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ABSTRACT

This report was compiled to serve as a reference on assessments of achievement in pre-college mathematics. Patterns of mathematical assessments are discussed in terms of the history and nature of assessments of achievement, the relationship between assessment and minimum competency testing, and the current status of state assessment programs. Trends in mathematics achievement are examined by presentation of portions of reports of the National Assessment of Educational Progress and the California Assessment, grades six and twelve. Conclusions drawn from examination of these assessment data include: (1) Although schools have been successful in teaching whole number computation, they have been only moderately successful with decimals and even less successful in teaching computation with fractions: (2) Students who know "how" to compute frequently do not know "when" or "where" to compute: (3) Schools must broaden their veiw of basic arithmetic if they expect students to use what they are taught. An extensive list of references is included. (MK)

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MATHEMATICS EDUCATION REPORTS

Assessing Mathematical Achievement

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Assessing Mathematical Achievement

The phenomenon of large-scale achievement testing is not new, but current interest is particularly high as assessments proceed across the nation. Many persons are searching for sources of information on these assessments. This document was therefore compiled to serve as a reference on assessments of achievement in pre-college mathematics. In Part I, the overall situation is concisely summarized, with comments on the history and nature of assessment and on the distinction between progress assessment and minimum competency testing. A table indicates the status of assessments in the 50 states. In Part II, analyses from one national assessment and one state assessment are presented. Finally, a list of pertinent references from the ERIC database and other sources is included. Thus, an indication of the current patterns and trends in the assessment of mathematical achievement is provided.

I. Patterns of Assessments

A. History and Nature of Assessments of Achievement

While achievement testing can be "traced back to antiquity" (Coffman, 1969, p. 8), its modern origins in the United States are generally considered to lie in 1897 with the research study by J. M. Rice on achievement in spelling. Studies on mathematics achievement soon followed, with Courtis (1909) among the leaders. As early as 1845, however, Horace Mann recognized the need for comparative data that could be provided by examinations.

> The recognition that a system of common examinations could be a means of raising standards within a state system of education led to the establishment, in 1865, of the Regents Examinations in the State of New York . . . (Coffman, 1969, p. 8)

Achievement tests have been recognized historically for their motivational quality, as well as for providing a basis for assigning grades and making selections. They are used to form classes, to place students, to evaluate curriculum as well as instruction, to identify exceptional children, and to interpret the schools to the community. However, their most significant role is as an integral part of the teaching-learning process:

> Their use in providing teachers with feedback regarding the effects of instructional procedures has been recognized, in principle if not often in practice. (Coffman, 1969, p. 9)

In a recent conference on testing, four purposes for tests were identified (Tyler and White, 1979, p. 3):

(1) Holding teachers, schools, and school systems accountable.

(2) Making decisions concerning individual students.

(3) Evaluating educational innovations and experimental projects.

(4) Providing guidance to teachers in the classroom.

For the past 15 years, there has been an attempt "to establish a systematic base for a continuous study of the progress of education within the United States" (Coffman, 1969, p. 9). In the National Assessment of Educational Progress (NAEP), samples of test questions have been administered to samples of age groups. This item-sampling approach

> differs markedly from the typical one involving standardized achievement tests in that the test item itself becomes the unit of interpretation in a manner similar to that of the polling studies, and generalizations are related to the achievement of broad subclasses of the population rather than to individual students, specific schools, or identifiable school systems. The conception is so different from the typical one that there has been widespread misunderstanding, [but] the development . . . should provide educational policymakers with significant information for decisions of broad significance. (Coffman, 1969, p. 9)

In addition to NAEP, testing programs in some individual states use the item-sampling technique. Where a broad picture of the status of achievement is desired, it is not necessary to have every child answer every item. With carefully controlled sampling of items and students, information about the status of achievement for the total group or for various subgroups can be obtained. However, when specific information about individual children is needed, then each child must answer all items of interest. In most local school testing programs, as well as in some statewide testing programs, this latter type of testing pattern is followed.

As systematic testing became a significant element in education, concern grew about the effects of misusing tests and test data.

> A standardized test readily takes on an aura of scientific precision far beyond that which its creator would claim. . . . Ebel (1964) has pointed to the dangers of overinterpretation of test scores. . . . Clearly, it is not enough simply to have mastered the technical aspects of testing. It is also necessary to develop an understanding of the context within which tests are used, to be aware of limitations and possible misuses, and to weigh a broad range of possible effects before deciding to use a particular context. (Coffman, 1969, p. 9)

Perhaps it is particularly important to note that an achievement test can provide only a measure of status at a particular time.

> . . . interpretation of achievement-test scores in relation to educational programs must of necessity involve, either explicitly or implicitly, the collection of data at two points in time. A single sample taken at a point in time can give no evidence of an "increase" in any attribute unless one is willing to make an assumption regarding the status of the student at some prior point in time. (Coffman, 1969, p. 7)

Unfortunately, educators all too frequently accept as evidence of achievement the performance of students at a single point in time without regard to differences in their achievement at some previous point in time.

> The result is that schools are credited with producing high-quality output when the output depends primarily on high-quality input, and pupils are charged with deficiencies in effort when they are actually achieving at normal levels in relation to their abilities and backgrounds. (Coffman, 1969, p. 7)

What should achievement tests do? Gronlund (1968, pp. 4-11) lists the following points:

(1) They should measure clearly defined learning outcomes, logically derived from instructional objectives.

(2) They should measure an adequate sample of the learning outcomes and subject-matter content included in instruction.

(3) They should include the types of test items most appropriate for measuring the desired learning outcomes.

(4) They should be designed to fit the particular uses to be made of the results.

(5) They should be made as reliable as possible and should then be interpreted with caution.

(6) They should be used to improve student learning.

As test procedures and results are analyzed, such points should be considered, both by those making broad decisions about educational policy and by teachers planning for groups of learners. While not limited to mathematics tests, they have particular implications for the assessment of mathematical learning.

As was noted earlier, testing of achievement in mathematics has been pursued from the early 1900s on, with extensive use of standardized testing in mathematics following the First World War. The purposes have varied, ranging from attempts simply to ascertain how well children were doing or what errors children were making, to the broader purpose of Washburne and the Committee of Seven during the late 1920s to resequence the curriculum in terms of test findings. The National Longitudinal Study of Mathematical Abilities was the first of the modern large-scale testing programs in mathematics (Wilson et al., 1968-1972). Planned and conducted by the School Mathematics Study Group (SMSG), it was not primarily concerned with assessment, but many of the procedures used parallel those in later assessments.

> NLSMA was conceived as a study of the effects of various kinds of mathematics textbooks on the learning of mathematics. Schools were recruited to participate at the fourth-, seventh-, and tenth-grade levels, and students in these initial samples were followed for five years, in order to detect long-term as well as short-term effects of curricula (Begle, 1975). SMSG exerted no influence on the choice of textbooks, nor were any consultant services or materials provided. Data on various characteristics of students and teachers were gathered, in addition to cognitive and affective scores. The mathematics tests were constructed in terms of computation, comprehension, application, and analysis objectives: an item bank was developed which has been used, in actuality or as a model, for myriad other studies. (Suydam and Osborne, 1977, p. 199)

At the time NLSMA was being planned, the goal of a national assessment across educational levels and subjects was coming to reality. The National Assessment of Educational Progress (NAEP), conducted by the Education Commission of the States, began assessment of various subject areas in the late 1960s. The first mathematics assessment by NAEP was conducted during 1972-73; the second was completed in 1977-78. In Part II, data from these two assessments will be presented. First, however, a more general point will be considered.

B. Progress Assessment and Minimum Competency Testing

Not infrequently, discussions of progress assessment turn into discussions of minimum competency testing. Is there a distinction, or can the two terms be used interchangeably?

The distinction between these two types of evaluation is often fuzzy--and occasionally non-existent. Yet they do differ. While minimum competency tests comprise one form of assessment, they possess certain features which distinguish them from progress assessments:

- Progress assessments are designed to determine the status of groups of children at one point in time, and to compare it with the status of similar groups at another point in time. Sometimes scores for individuals are determined, and used by teachers to help individuals. But the focus is on how well -- or poorly -- the group of children at, say, sixth-grade level, has achieved a spectrum of mathematical objectives.

- Minimum competency testing, on the other hand, is designed to measure the acquisition of specified knowledge and skills to or beyond a specified standard. Each individual is expected to attain at least the minimum standard, and thus demonstrate competency with the knowledge and skills which, by one means or another, have been specified as "necessary." Moreover, another feature of minimum competency testing is that the test score may be used to determine whether or not the individual will be promoted from grade to grade, or graduated from high school.

On this latter point the definition becomes particularly hazy, because it is not an aspect of all programs termed minimum competency. Thus, some states--for example, Massachusetts, Missouri, Nebraska, and New Hampshire--are popularly reported as having minimum competency testing, but they do not use the test scores as a basis for graduation or promotion. Many persons maintain, however, that this is a key aspect of minimum competency programs. Taylor, for instance, argues:

> Minimum competence is useful, not as a term with universally accepted meaning, but rather as a term with specific meaning in a specific situation, such as a graduation requirement for a particular school. Then, minimum competence can be defined and measured, and decisions can be made on the basis of whether a student can demonstrate the attainment of the particular minimum competence. (Taylor, 1978, p. 89)

It is important to note that in progress assessments, the focus is on the status of a group of learners. Assessments are used to survey trends in achievement or to detect weaknesses in the curriculum. Often, as in Minnesota,

> Not every student is assessed at the grade levels where the Assessment Program focuses, nor is every district included in each assessment. Instead, a stratified sample is used, based on five sizes and types of districts, and results from these groups reported along with state results. (Allen and Sushak, 1979, p. 1)

A legislator from California, Leroy F. Greene, State Assemblyman and Chairman of the Education Commission, adds this view:

> Parents, communities, and the legislature also want to know the cost and the benefits of the education system as a whole, and for this we need state-level assessment. . . . State-level testing and assessment programs should not identify any pupil participating in such assessment, but rather should serve as a tool for measuring the educational progress of schools, school districts, and the state's education system. State level assessments are not a proper instrument for diagnosing the needs of an individual student or for determining whether a student should be promoted, retained, or graduated. (Greene, 1978, p. 7)

On the other hand, the emphasis in minimum competency testing is on the individual student. The individual is affected by the test: he or she is labeled competent or incompetent. Whether or not each particular student will be promoted or graduated is at stake.

The growth of progress assessment and in particular minimum competency testing has been reported for some years by Pipho of the Education Commission of the States. He noted that

> What began as a startling idea in California, Florida, Oregon, and a handful of other states in 1975 and 1976 has now arrived in some form in each state. As of March 15, 1978, 33 states had taken some type of action to mandate the setting of minimum competency standards for elementary and secondary students. All the remaining states either have legislation pending or legislative or state board studies under way. (Pipho, 1978, p. 585)

As of May 1979, 19 states were reported as requiring students to pass a minimum competency test for graduation, while others used it for promotion from junior high school to high school or for determining the need for remedial work (Newsweek, 1979, p. 97). Some states have developed a high school graduation test (e.g., New York), or a high school equivalency test (e.g., California and Florida) (ETS, 1977, p. 2). In other instances, local school districts have taken the initiative independent of state action, often with pressure from local parent groups.

Why have progress assessment and minimum competency testing "swept the country"? Many analyses have concluded that both are results of the movement toward accountability, which the public demanded increasingly during the 1970s. The rallying cry of "back to the basics" led to a headlong rush into minimum competency testing. Clark and Thomson (1976, p. 5) cited the following reasons for "the public's determination to define the high school diploma":

- Scores on the Scholastic Aptitude Test have fallen, and the American College Testing program also reported a decline in the average scores of students applying for college admission.

- The National Assessment of Educational Progress in 1975 reported a decline in some scores.

- NAEP also reported in a nationwide survey of 17-year-old students and young adults that many consumers are not prepared to shop wisely because of their inability to use fundamental mathematical principles such as figuring with fractions or working with percents.

Another report cited varied reasons for the support of minimum competency testing by different groups (Miller, 1978, p. 5):

Parents: they fear that children have been passed through the system without proper concern for developing the skills necessary for success in adulthood.

Taxpayers: they ask educators to explain why educational costs are rising while enrollment and test scores decline.

Employers: they are disappointed in the pool of applicants available: many employees have difficulty with such tasks as filling out forms, answering telephones, and simple computation.

Officials in institutions of higher learning: they are unhappy about the decline in Scholastic Aptitude scores and the need for remedial courses for entering freshmen.

Critics of the schools: they hope that this issue will help create support for restructuring the schools according to their particular goals.

Some persons identify a more complex reason for the call for proficiency standards. They argue that

> it is a response to a particular political and fiscal stimuli. High real property and personal income tax levels for some groups and the problems some middle class kids have reading and getting into professional schools lie behind the cry for accountability. The latter problem is really that the middle classes cannot use the public schools for the purposes to which they are accustomed . . . the meritocracy is working and more middle class children are excluded from the rewards of advanced education. (Kelley, 1977, pp. 3-4)

Others have similarly noted that political considerations and financial constraints are the major factors influencing administrative decisions. For instance, as a prelude to discussion of mathematics testing, Taylor (1979) stated:

> Dollars from local taxes are getting even more scarce. The passage of Proposition 13 in California is a signal that taxpayers are "fed up" with taxes in general and property taxes in particular. The effects of this so-called "taxpayer revolt" are being severely felt by school systems throughout the country. (p. 98)

He urges that there is need for a systematic approach to developing cost-effective programs of instruction and testing, rather than making educational decisions on a "crisis orientation," with the creation of crisis as one way to get a decision (p. 108).

Furthermore, he is among the many educators who have warned of potential harm from minimum competency testing programs, at least as they are presently being mandated and implemented. He points out that many programs were hastily conceived,

> with the naive assumptions that higher achievement could be legislated, that no special funds were needed for testing and remediation programs, and that suitable tests were readily available. (Taylor, 1979, p. 98)

In some instances, educators have been bypassed as programs were established. The pattern in Virginia is not totally unique: legislation was enacted, mandating the development of minimum competency objectives and tests with which to assess them, with little interaction with educational agencies in the state. State departments of education and local school districts were given a relatively short period of time to implement the legislative mandate. Educators had no direct role in the decision-making process, nor was the rationale for the decision-making process clear (Suydam and Osborne, 1977, p. 210).

A major difficulty connected with any competency program is the matter of determining what a minimum level of competency is.

> How much should a student master? What constitutes "functional literacy"? How many competencies are

> enough? . . . A related concern is that imposing an arbitrary cut-off will result in too many youngsters failing the test, with the poor and minorities most directly affected . . . Another objection voiced often is that minimum requirements will become the maximum, that levels of proficiency will be set so low that they will become worthless. (ETS, 1977, pp. 2-3)

As experience with minimum competency testing increases, answers to some concerns have appeared. Action in legislatures, state departments of education, and schools is becoming "more deliberate and considerate as the complexities of testing and the other issues emerge" (Taylor, 1979, pp. 98-99). The need for incorporating intensive remedial instruction into programs is becoming clear: achievement of competency cannot simply be mandated, but must be developed through long-range planning. Therefore, some means of attaining competency must be available for those who have failed to demonstrate it on the test. Fears that relatively low levels of proficiency will become maximum standards are still present, but also present is concern for readjusting the curriculum to reflect the fundamental competencies that all citizens must have in today's--and tomorrow's--world.

The Position Paper on Basic Skills, published by the National Council of Supervisors of Mathematics (NCSM), provides a basis for such efforts. It was noted that, in many minimum competency statements, "computation" or "arithmetic" was stipulated. The NCSM cautioned against this narrow definition, and proposed that ten skills are basic in mathematics:

- Problem solving
- Applying mathematics to everyday situations
- Alertness to the reasonableness of results
- Estimation and approximation
- Appropriate computational skills
- Geometry
- Measurement
- Reading, interpreting, and constructing tables, charts, and graphs
- Using mathematics to predict
- Computer literacy

They noted that computation is an element of each of these skills, but computational skills per se constitute only one of the ten skills listed. Tyler and White (1979) therefore noted:

> As mathematics teachers increasingly emphasize these other basic skills, tests used to assess their success in teaching must contain an appropriate selection of

> items in these other areas. Similar needs exist elsewhere in the curriculum. The more broadly conceived skills being called for in mathematics and elsewhere are often ones that reflect the needs of adults in analyzing and solving practical problems that confront them in their jobs and personal lives. Similar objectives--such as the ability to solve practical problems involving computation and reading --are found in a number of the competency tests being devised by the States. (p. 15)

Taylor (1979) added that

> Universal agreement on minimum competence necessary for all citizens is not likely to be achieved. If minimum competence is to be defined, it should be done at the local level. Then if the distinction between basic skills and minimum competence is maintained, the broad concept of basic skills will not be narrowed or compromised. (Taylor, 1979, p. 102)

The NCSM Position Paper also contains a statement about testing, pointing out that, if properly conceived, conducted, and interpreted, testing can be educationally beneficial.

> Large-scale testing, whether involving all students or a random sample, can result in interpretations which have great influence on curriculum revisions and development. Test results can indicate, for example, that a particular mathematical topic is being taught at the wrong time in the student's development and that it might better be introduced later or earlier in the curriculum. Or, the results might indicate that students are confused about some topic as a result of inappropriate teaching procedures. In any case, test results should be carefully examined by educators with special skills in the area of curriculum development (NCSM, 1977).

Progress assessment, and minimum competency testing, are a fact of the current educational scene. That there is considerable overlap and confusion between the two terms should be apparent. Assessment does not necessarily imply the setting of standards, but neither does it guarantee that standards will not be set or sanctions imposed on students who do not meet those standards. One of the most articulate indictments of less-than-careful testing is given by Shirley Hill, president of the National Council of Teachers of Mathematics.

> The public wants high test scores now--never mind what we are testing and never mind its potential for obsolescence. Just get higher scores than the school district down the road. Or be sure you make the year's Top Ten in Minimal Competencies . . . Dramatic, rapid

> gains in scores should be a danger signal. How concentrated and limited was the effort? Does it concern itself with long-term retention and application? At the expense of what else have these gains been achieved? These questions should be asked, and the means employed should be carefully examined. (1979, p. 2)

C. Status of State Assessment Programs

One of the original goals of this report was to present a clear picture of the status of mathematics achievement assessments across the country. To accomplish this task, we turned to existing documents that have reported survey results and other compiled information (e.g., ETS, 1977; Hawthorne, 1974; Kauffman, 1979; Olney, 1977; Pipho, 1979; Porter and Wildemuth, 1976; Suydam and Osborne, 1977), as well as reports from individual states. We anticipated collating information on such factors as the type of assessment (status or progress assessment, or minimum competency), the vehicle through which action was to be initiated (legislature, state department or board of education, or local education agency), the years in which assessments were conducted, the type of test used (standardized or non-standardized), the grade or age levels involved, and the number of students tested.

The task was not as simple as it seemed. Not only is a great deal of information inaccessible; even worse, many instances of contradictory information became evident. As one example of this, several documents stated that the Louisiana Assessment did not include mathematics; however, we recovered from ERIC a report on the Louisiana Mathematics Assessment! Confusion over definitions of assessment and competency testing we had anticipated; we did not anticipate the great difficulty in reconciling type of action, dates, levels, and other factors. In fact, "reconciliation" is hardly an appropriate word: we had to use subjective judgment in an attempt to determine what conflicting information meant. (In the case of "level," we simply noted alternatives cited.) In some cases, this judgment was correct; in others, errors may be found. While some information is "second-hand" from the reports of compilers, other information was obtained directly from documents from the individual states. Unfortunately, information and documents from all states were not located or obtained. (Had we resorted to our own survey to obtain the needed information, the "percentage correct" might have been slightly higher. It should be noted, however, that conflicting information has arisen from previous surveys. Apparently, perceptions of respondents have differed--and in some cases, a low return rate added to the difficulty of obtaining accurate information.)

We could merely have noted that confusion exists, and that to obtain a precise, accurate indication of the status of achievement assessments in mathematics across the states is impossible. Instead, we chose to present the information that we have been able to glean.

The table that follows is incomplete: the gaps are obvious. (Thus, we did not list dates when we thought assessments were probably conducted; we listed only what we could verify.) Please do not forget that it might also contain incorrect information, even though we tried to include only that which was affirmed by several sources. In the reference column are listed documents in the ERIC system from which detailed information can be obtained, plus selected other documents included in the list of references in this publication. There undoubtedly exist other documents which we were not able to locate. Additional information on progress assessments may be requested from the states (although not all have this information available for distribution).

ASSESSMENTS IN THE STATES

State	Type[1]	Action	Conducted	Test[2]	Levels	N	ERIC Reference Numbers[3]
Alabama	P/M	State	1979 (pilot)	N	3,6,9 (4,6,8)	7 systems	
Alaska	O/M	LEA	1977			7 districts	
	O/A			N	4,8		
Arizona	O/M	State	1976		8,12 (3,5,8,12)		
	O/A		1971-72	S/N	8	35,866	P: ED 077 935 (1972)
			1974		6	4,047	ED 088 710 (1974)
			1974-75		5		O: ED 147 348 (1977) [See also SE 028 932, 1976.]
Arkansas	P/A	State/ LEA	1971-72 1972-73	S	3,4,8,9 3,8	28 districts	
California	O/A	Legis.	1974-75 1978-79	N	6,12	all	O: ED 022 767 (Kelley et al., 1968) ED 059 910 (1977) P: ED 124 592 (1975) ED 127 358 (1975) ED 129 594 (Hoffman and Tardif, 1976)
	O/M	LEA	(1980)				[See also California, 1963.]

[1] P = Planning; S = Studying; O = Operating; M = Minimum Competency; A = Assessment.

[2] S = Standardized; N = Non-standardized.

[3] N = Needs assessment; O = Objectives; P = Progress assessment.
Where no author is given, document is in References under name of state.

State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Colorado	O/M	Legis./ LEA	1971	N	5		P: ED 139 835 (Hennes, 1977)
	O/A		1970	N	3,6,9,12		ED 050 135 (Helper, 1970)
Connecticut	O/A	Legis./ State	1976-77		ages 9, 13,17	all	P: ED 166 019 (Ghiselin et al., 1977) ED 166 020 (Rubenstein and Ghiselin, 1977)
Delaware	O/A	State	1970	S	1,4,8		O: ED 100 057 (1975)
			1971		1,4,8		ED 104 945 (Wise et al., 1975)
			1972		1,4,8		ED 118 608 (Handrick, 1975
			1973		1,4,8		ED 135 848 (1977)
			1974		1,4,8		ED 144 832 (Wall, 1977)
			1975		1,4,8		
	O/M	State			11	all	
District of Columbia	O/A		1972	N	1-9	all	N: ED 104 902 (1972)
	P/M		1979 (pilot)	S	3,6,9,12	all	
Florida	O/M	Legis.	1971	N			
			1972-73		3,6,9		N: ED 100 045 (1972)
			1973-74			120,000	
			1974-75		3,6,9		
			1975-76		3,5,8,11		
Georgia	O/A			N	4,8,11	all	N: ED 107 695 (1974)
	O/M	State	(1981)		9		

State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Hawaii	O/A		1965-70	S	4,8		P: ED 074 441 (1971)
			1970-71		4,6,8 10,12	65,000	ED 081 839 (1972)
			1971-72				
	S/M	State	(1983)				
Idaho	O/M	State/ LEA	1978	N		50%	
Illinois	P-O/M	Legis./ State	1978	N		20-80%	
Indiana	S/M	State	1980	N	3,6,8,10		
Iowa	O/A	LEA	1975-76	S	5,8		P: ED 125 894 (Morrison, 1976) N: ED 169 105 (McNully, 1978)
	S/M	State					
Kansas	O/M	LEA	1970	N	3,5,8,10,12 (6,12)		
	P/A	Legis./ State	1978 (pilot)	N	2,4,6,8,11 (3,6,9,12)		
Kentucky	O/A	State	1973	S	4	3,741	O: ED 081 793 (1971)
					8	3,389	
					11	2,702	
			1974		8	7,226	
			1975		2	3,981	
					4	7,067	
					8	7,076	
					11	6,019	
	P/M	Legis./ State	1978	S	3,5,7,10 (3,5,8,11)		

State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Louisiana	O/A	Legis.	1974-75	N	ages 9, 13,17		P: ED 141 119 (1976)
Maine	O/A	Legis.	1977	N	8,11		
Maryland	O/A	Legis.	1975-76	S,N	3,5,7,9		O: ED 162 864 (1978) N,P: ED 118 635 (1975) ED 118 637 (1975) ED 118 638 (1976)
	O/M				3,5,7 (3,7,9,11)		P: ED 135 865 (Convey et al., (1977) ED 158 238 (1977)
Massachusetts	O/A	State	1974-75	N	ages 9, 13,17	17,600	N: ED 109 769 (1971)
Michigan	O/A	State	1970-71 1971-72 1972-73 1973-74 1974-75 1975-76 1976-77 1977-78 1978-79	N	4,7 4,7 4,7 4,7 1,4,7 1,4,7,10	320,000	O: ED 053 217 (1971) ED 059 255 (1971) ED 059 257 (1971) ED 073 139 (Donovan et al., 1972) ED 104 897 (1973) ED 104 898 (1972) ED 104 899 (1973) ED 104 966 (1972) ED 104 967 (1974) ED 111 832 (Roeber and Huyser, 1975) ED 120 216 (Donovan, 1973) ED 120 217 (Donovan et al., 1973) ED 120 218 (Mehrens, 1975) ED 120 219 (Fisher et al., 1973) ED 120 220 (1974) ED 120 221 (1975)

State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Michigan (cont.)							O: ED 120 225 (Fisher et al., 1974) ED 120 226 (Roeber et al., 1974) ED 164 578 (Roeber and Brictson, 1978) P: ED 117 173 (1975) ED 120 242 (1974) ED 127 131 (Zoet, 1974) ED 127 132 (Coburn et al., 1975) ED 127 133 (Beardsley et al., 1974) [See also Coburn, 1979; McCormick, 1978.]
Minnesota	O/A	State	1971-72 1974-75	N	age 9, 13,17 age 9 age 13 age 17	 12,000 17,000 16,000	P: ED 084 657 (Pyecha, 1973) ED 089 464 (Adams and Johnson, 1973) ED 137 541 (Ludeman, 1976) [See also Allen and Sushak, 1979.]
Mississippi	S/M	State	1971-74	S	5,8 (4-9)		
Missouri	O/A	State	1970-71 1974-79	N	4 6 8	8,034 8,266 all	P: ED 070 056 (1971) ED 077 990 (1971)
Montana		LEA					O: ED 062 212 (1972)
Nebraska	O/A	State	1975	N	5 until mastery	all	O: ED 166 250/251/252 (Kennedy, 1978)

State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Nevada	O/A		1971-72		3		N: ED 079 822 (Howard and Ogg, 1971)
			1972-73		3	2,392	
					4	2,315	
			1973-74		3	2,420	
					5	2,376	
					7	2,750	
	O/M	Legis.	1978	S	3,6,9,12	all	
New Hampshire	O/A	State	1967	S	4,8,12		N: ED 097 352 (Schweiker, 1974)
			1978 (pilot)	N	4,8,12	7,500	P: ED 039 147 (Austin, 1969) [See also Austin and Prevost, 1972.]
New Jersey	O/A	State	1972-73	N	4,12		P: ED 074 129 (Ascher, 1973)
		Legis.	1975-76		4	96,000	ED 097 396 (Gurwitz, 1974)
					7	109,000	ED 127 352 (undated)
					10	109,000	
			1978	N	3,6,9,11		
New Mexico	O/A	State	1969	S	5		N: ED 077 938 (Klein, 1972)
			1973-74		5,8,12	70,000	ED 079 422 (1973
			1978	N	5,8,12 (5,8,10,11)		ED 095 631 (1974)
New York	O/A	State	1966-72	S	3,6,9	all	P: ED 071 162 (1972)
			1973-79				ED 080 591 (1973)
North Carolina	O/A		1973-74	S	6		N: ED 106 294 (1975)
			1974-75		3	5,000	ED 108 974 (1974)
			1975-76		9		
	O/M	Legis.	1977 (pilot)		1,2,3,6, 9,11	all	
North Dakota		LEA					

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State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Ohio	O/A	Legis./ State		N	4,8,12		N: ED 096 745 (1973)
Oklahoma	P/A	State	1977 (pilot)		3,6,9 (Reading) 12 (Survival skills)		
Oregon	O/M	State	1976	N	4 4,7,11	8,000	N: ED 109 207 (Thomas, 1975) ED 139 664 (1976) [See also Clemmer, 1970.]
Pennsylvania	O/A	Legis./ State	1970 1976	S N	5,8,11		O: ED 090 252 (Kendig, 1974) ED 093 943 (Coldiron, 1974) P: ED 068 471 (1971) ED 166 198 (Kim, 1978)
Rhode Island	O/A	State	1972 1973	N,S	4,8 4,8 4,8,11		
South Carolina	P/A	Legis.	1978 (pilot)		4,7,9,11 (3,6,11/ 1,2,3,6,8,11)		
South Dakota	O/A	LEA		S	3,6,9		
Tennessee	P/M	State	(1981)	N	8,10 (4,5,6,8,11,12)		
Texas	P/A	State	1971 1977-78	N	6 6,11	22,055	P: ED 071 879 (1972) ED 164 591 (1978) ED 164 625 (1978) ED 167 683 (1979) ED 169 133 (1978)

State	Type	Action	Conducted	Test	Levels	N	ERIC Reference Numbers
Utah	O/A		1975	S	5	4,000	N: ED 079 825 (Campbell and Forsgren, 1970)
					11	3,000	
			1978	S	5	4,000	ED 169 119 (Ellison et al., 1978)
					12	2,000	
	O/M	State	(1980)		9-12		[See also Utah, 1974; Ellison et al., 1975.]
Vermont	O/M	State	1978		k-12	all	
Virginia	O/M	Legis.	1978		k-12 (1-6,8,10,11)	all	[See Virginia, 1976.]
Washington	O/A	Legis.	1971	S	4	6,763	P: ED 086 725 (Brouillet, 1973)
					6	6,881	
			1977		4,8,11		
West Virginia	O/A	State		S	3,6,9,11	all	O: ED 166 234 (1978)
Wisconsin	O/A	State	1969	N			O: ED 051 186 (Henderson et al., 1971)
			1973	S	3,7		ED 069 475 (Henderson et al., 1973)
			1977	S,N	4,8,12		P: ED 096 320/325/328 (1974)
							[See also Coulson and Howe, 1977.]
Wyoming	O/M	State					

II. Trends in Mathematics Achievement

In this section, data from the two mathematics assessments conducted by the National Assessment of Educational Progress will be presented, and apparent trends in mathematics achievement will be identified. To provide additional information on achievement trends, an analysis of the mathematics portion of the California Assessment Program from 1975 to 1979 will be cited. These data both supplement and contrast with the NAEP data.

A. Trends in Mathematics Achievement from the National Assessment of Educational Progress*

The National Assessment of Educational Progress (NAEP) has completed two surveys of the mathematics achievement of 9-, 13-, and 17-year-old students, the first conducted during the 1972-73 school year and the second five years later, during 1977-78. Described here are changes in student performance in mathematics between the 1973 and 1978 assessments.

The 1977-78 mathematics assessment was designed to measure students' abilities at four different cognitive process levels crossing a variety of traditional mathematics content areas. These cognitive process levels are: (1) knowledge, (2) skills, (3) understanding and (4) application. Major content areas assessed are numbers and numeration; variables and relationships; geometry (size, shape and position); measurement; and "other topics," including probability and statistics, and graphs and tables. For a more complete description of the development of the 1977-78 mathematics assessment, refer to *Mathematics Objectives, Second Assessment* (NAEP, 1978).

The knowledge level of cognitive process involves recall of facts and definitions, and includes such topics as number order; place value; basic facts of addition, subtraction, multiplication and division; geometric figures; and measurement units. Skills involve the ability to use specific algorithms and manipulate mathematical symbols. Included in the skills level of cognitive process are computing with whole numbers, fractions, decimals, percents and integers; taking measurements; converting measurement units; reading graphs and tables; and manipulating geometric figures and algebraic expressions. Understanding implies a higher level of cognitive process than simply recalling facts or using algorithms. Exercises assessing mathematical understanding asked students to provide an explanation or illustration of different mathematical knowledges or skills, requiring a transformation of knowledge but not the application of that knowledge to solve a problem. Application requires the the use of mathematical knowledge, skills and/or understandings--typically in problem-solving activities.

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*The following material is a reorganization of the NAEP report Changes in Mathematical Achievement, 1973-78, pp. 1-16. Essentially all material is quoted directly.

Measuring Changes in Achievement

Testing conditions must be as nearly the same as possible in each assessment to assure an accurate measure of *changes* in performance. National Assessment made every effort to hold conditions constant by reading instructions and items on tape to students and by using trained administrators, rather than classroom personnel, to conduct the assessment. Items used to measure change were identical in wording and format in each survey, and time allowed for students to respond was the same. Comparable samples of young people were drawn for each assessment year.

As previously stated, identical sets of items were used in each assessment year to measure changes in performance. Overall changes in mathematics achievement were based on 55 item parts for 9-year-olds, 77 item parts for 13-year-olds, and 102 item parts for 17-year-olds. Between 2,100 and 2,500 students at each age responded to an item in each assessment. Items were packaged in booklets, and any one student completed only one booklet of about 45 minutes in length. In 1977-78 there were 7 booklets for 9-year-olds, 11 for 13-year-olds, and 12 for 17-year-olds. Approximately 17,000 9-year-olds, 27,000 13-year-olds, and 27,000 17-year-olds participated in the mathematics assessment.

Thirteen-year-olds were assessed in October through December in both the first and second assessments; 9-year-olds, in January and February; and 17-year-olds, in March and April. Thus, the amount of school experience for each age group was approximately the same in each assessment.

Item scoring also remained consistent across assessment years. Approximately 20 percent of the items used to measure change were multiple-choice. These were scored by an optical scanning machine; the same answers were scored correct in each assessment year. The remaining 80 percent of the items were open-ended, meaning that respondents had to supply the correct answer. Scoring guides for open-ended items, which define categories of acceptable and unacceptable responses, were revised in 1978. All 1973 responses were rescored at the same time that the 1978 responses were scored, using the 1978 scoring guides, to insure that scoring of the two sets of data was the same.

Reporting the Data

Differences in average or item-level performance between assessments are described as changes *only* if the differences are statistically significant at the .05 level; differences that are not significant at that level are described as being "not appreciably different." However, it should be remembered that changes may be statistically significant but still not large enough to be meaningful. A positive difference in performance for a certain average or item indicates that more people made a correct response in 1978 than in 1973; a negative difference shows that fewer people made a correct response in the second assessment than the first.

Changes at Different Cognitive Levels

Mathematical Knowledge

Items assessing knowledge stressed recall and recognition of facts and definitions--including the names of numbers, number order, and the names of geometric figures. Average results for all items in the knowledge section showed no appreciable change for any of the three NAEP age groups.

However, exercises assessing knowledge of the metric system of measurement--one administered to 13-year-olds and two administered to 17-year-olds--showed very substantial gains (26 percentage points for the 13-year-olds' item; 12 and 15 percentage points for the 17-year-olds' items). These gains were large enough to affect substantially the average results for all items. When the three metric items were removed from the knowledge averages, both 13- and 17-year-olds showed decline in mathematical knowledge as summarized in Table 1.

TABLE 1. Changes in Average Performance on Mathematical Knowledge Items when Metric Items Were Omitted

	Number of Items	Average Performance 1973	1978	Change in Average Performance
Age 9	17	55%	55%	-1% +
Age 13	15	67%	65%	-2%*
Age 17	16	63%	62%	-2%* +

Mathematical Skills

Mathematical skills involve the ability to manipulate mathematical symbols or use an algorithm--for example, adding a column of numbers, reading information from a table or solving a given equation. Average results for skill items showed that 9-year-olds' skill levels did not change between 1973 and 1978. However, average skill levels of 13- and 17-year-olds declined, with 17-year-olds showing the larger drop. Results for items measuring specific mathematical skills are presented in Table 2.

+ Figures do not total because of rounding.

TABLE 2. Changes in Average Performance on Mathematics Skills Items Assessed in 1973 and 1978

	Number of Items	Average Performance 1973	Average Performance 1978	Change in Average Performance
Age 9	21	26%	26%	0%
Age 13	37	51%	49%	-2%*
Age 17	46	55%	50%	-5%*

**Change is significant at the .05 level.*

Mathematical Understanding

Understanding implies a higher level of cognitive process than recalling facts or using skills. It involves the ability to grasp the principles underlying various knowledges or skills. Exercises measuring understanding often required students to translate knowledge or skills from one form to another, for example, substituting one form of mathematical expression for another, or providing an explanation or illustration of a particular knowledge or skill.

Understanding was not heavily emphasized in the first assessment of mathematics, and thus there are relatively few items measuring changes in this area, especially for 9-year-olds. Performance of 17-year-olds declined on these items. The decline for 13-year-olds is very close to significance at the .05 level ($p < .06$) and perhaps should be viewed as a decline (Table 3).

TABLE 3. Changes in Average Performance on Mathematics Understanding Items Assessed in 1973 and 1978

	Number of Items	Average Performance 1973	Average Performance 1978	Change in Average Performance
Age 13	12	52%	50%	-2%
Age 17	13	62%	58%	-4%*

**Change is significant at the .05 level.*

Mathematical Application

Mathematical application involves the use of mathematical knowledge, skills, and understanding to solve problems. Problem solving requires judgment--the ability to determine which facts, algorithms or understandings are relevant--as well as the ability to apply the needed processes.

Major emphasis in the application items was on solving typical textbook word or story problems. Some of these problems involve the use of geometry, measurement, probability and statistics, or graphs and tables. A small number of problems were classified as "non-routine," meaning that students most likely would not have encountered similar problems in mathematics textbooks and would have to solve them without benefit of prior experience with similar problems.

All three age groups showed significant average declines on the applications items (Table 4). Nine- and 13-year-olds responded to a relatively small number of items, so results for them should be interpreted with some caution.

TABLE 4. Changes in Average Performance on Mathematics Applications Items Assessed in 1973 and 1978

	Number of Items	Average Performance 1973	Average Performance 1978	Change in Average Performance
Age 9	9	38%	32%	-6%*
Age 13	12	42%	38%	-3%*+
Age 17	25	33%	29%	-4%*

**Change is significant at the .05 level.*

†Figures do not total because of rounding.

Changes in Whole Number Arithmetic and Number Properties

Several items measured students' ability in whole number arithmetic and grasp of number properties across the knowledge, skill, understanding, and application levels.

Nine-year-olds' performance did not change on two items requiring them to write and order whole numbers. Approximately 88 percent in each assessment correctly wrote "five hundred twenty-two" in numerical form after seeing and hearing it in the verbal form. About 85 percent correctly ordered 4 two-digit numbers, several of which contained the same digits in different places. Thirteen-year-olds were even more successful on this task--around 96 percent of them correctly ordered the four numbers in each assessment.

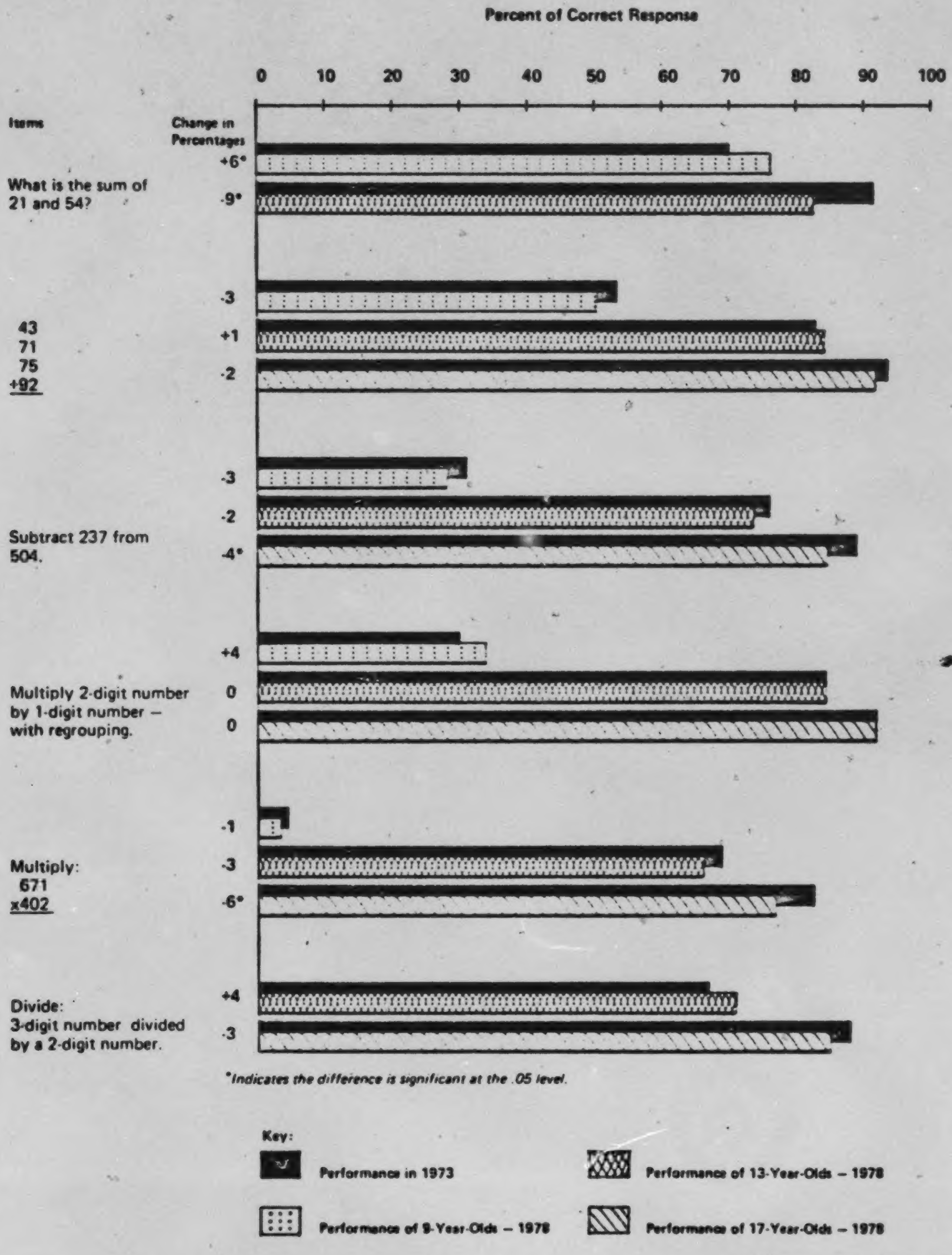
Nine-year-olds' performance also did not change on several items dealing with number theory and the properties of numbers. Around 70 percent in each assessment could list two even numbers and two odd numbers. About 60 percent knew that a number multiplied by one equals itself, and about half knew that a number divided by one equals itself.

Figure 1 on the next page shows skill levels in 1973 and 1978 on various whole number computational tasks. On the first item ("What is the sum of 21 and 54?"), which does not require regrouping (carrying), approximately three-quarters of the 9-year-olds and just over four-fifths of the 13-year-olds were successful in 1978. Nine-year-olds improved between 1973 and 1978 while 13-year-olds declined. Nine-, 13-, and 17-year-olds' abilities to add the column of numbers with regrouping did not change appreciably over the five-year period. On the subtraction item, which required students to regroup (borrow) twice, performance of 9- and 13-year olds did not change, but that of 17-year-olds dropped by 4 percentage points. Ability to solve the simple multiplication item remained constant for all three age groups; however, 17-year-olds declined in their ability to solve the more complex multiplication item. Skill in answering a simple long division exercise stayed about the same for both groups of teenagers, with 71 percent of the 13-year-olds and 85 percent of the 17-year-olds answering correctly in 1978.

On these examples, the whole number computational skills of 9- and 13-year-olds appear to have remained relatively stable. Seventeen-year-olds may have lost some ground in their skills with more complex computations.

Understanding of number theory and the properties of numbers and operations were also assessed. Nearly 60 percent of the 13-year-olds and 75 percent of the 17-year-olds in each assessment identified a general algebraic expression for an odd number. Approximately 70 percent of the 9-year-olds in each assessment understood that if a X b = 84, then b X a also equals 84, an example of the commutative property of multiplication. Performance dropped on two items concerning number relationships. As seen in Figure 2, fewer 13- and 17-year-olds in 1978 than in 1973 realized that the relationships of the two variables given could not be determined. In a problem dealing with the transitive property of the relation "older than," 50 percent of the 9-year-olds, 72 percent of the 13-year-olds, and 81 percent of the 17-year-olds chose the right answer in 1978, declines of 5, 10 and 5 percentage points, respectively. Understanding that the associative property--for example, $(a + b) + c = a + (b + c)$--applies to addition and multiplication but not to subtraction or division also decreased for the teenaged groups. In 1978, 48 percent at age 13 and 64 percent at age 17 demonstrated this understanding, representing declines of 11 percent for 13-year-olds and 10 percent for 17-year-olds.

FIGURE 1. Percentages of Correct Response on Whole Number Computation Items—1973 and 1978, Ages 9, 13 and 17



**Indicates the difference is significant at the .05 level.*

(NAEP, 1979)

FIGURE 2. Percentages of Correct Responses on Item About Relationships of Variables Assessed in 1973 and 1978

If a > 5 and b > 5, then

○ a equals b.

○ a is greater than b.

○ b is greater than a.

● there is not enough information to determine the relation between a and b.

○ I don't know.

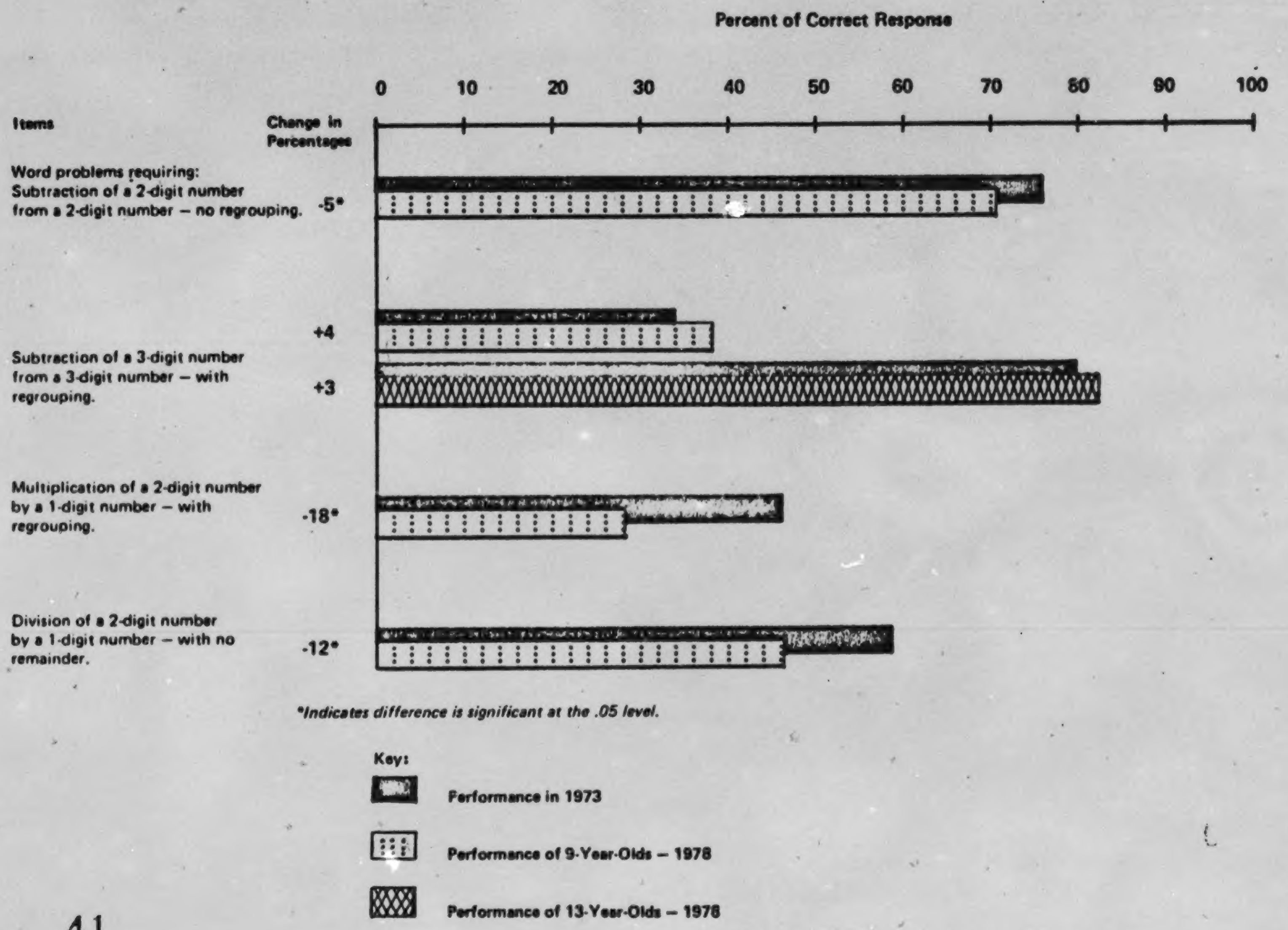
	Percent Correct 1973	Percent Correct 1978	Change
Age 13	67%	57%	-10%*
Age 17	83%	76%	- 7%*

**Change is significant at the .05 level.*

Whole-number computation is an important part of much problem solving. In the simplest single-step problems, only one arithmetic operation is applied to the problem.

Figure 3 displays 9- and 13-year-olds' performance on four single-step word problems. Results for 9-year-olds declined on the easier subtraction task but tended to improve on the more difficult problem, which required subtraction of a three-digit number from a three-digit number. Thirteen-year-olds were considerably more proficient than 9-year-olds on the same subtraction problem; their percentage of success also tended to improve. The numbers in the subtraction word problem given to both 9- and 13-year-olds were also presented as a strictly computational item. Approximately 50 percent of the 9-year-olds in 1978 subtracted correctly on the computational item, compared with 38 percent correctly answering the word problem. The difference for 13-year-olds was much smaller, with 85 percent correctly solving the computational item and 82 percent, the word problem. As seen in Figure 2, 9-year-olds' abilities on the word problems that required multiplication and division declined rather sharply.

FIGURE 3. Percentages of Correct Response on Single-Step Word Problems—1973 and 1978, Ages 9 and 13



(NAEP, 1979)

Multistep problems require more than one operation for their solution. Most of these were administered only to 17-year-olds. The problem shown in Figure 4 can be solved first by dividing to find the number of five-minute intervals in an hour and then multiplying the number obtained by eight kilometers. Seventeen-year-olds' performance dropped considerably on this item.

FIGURE 4. Percentages of Correct Responses on Multistep Problem Assessed in 1973 and 1978

A car traveled eight kilometers in five minutes. At this speed, how many KILOMETERS could it travel in one hour?

Answer (96 km)

	Percent Correct 1973	 1978	Change
Age 13	31%	28%	- 3%
Age 17	65%	56%	-10%*†

**Change is significant at the .05 level.*

†Figures do not total because of rounding.

Changes in Ability to Use Fractions, Decimals, and Percents

Several NAEP items measured knowledge, skills, understanding, and abilities for rational number arithmetic--work with fractions, decimals, and percents.

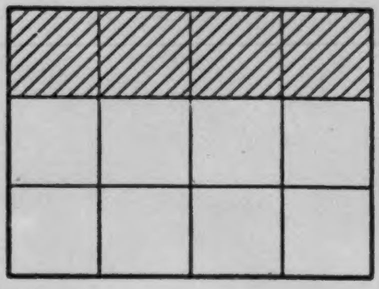
Items requiring the ordering of fractions and decimals seemed more difficult for teenagers in 1978 than in the previous survey. In 1978, 52 percent of the 13-year-olds and 81 percent of the 17-year-olds correctly selected a common proper fraction falling between two given common proper fractions. Performance on this item dropped from the 1973 assessment--6 percentage points for 13-year-olds and 4 percentage points for 17-year-olds. Relatively few 13-year-olds in either assessment--about 15 percent--identified a decimal number falling between two given decimal numbers. Forty-six percent of the 17-year-olds were successful at this task in 1978, a decline of 7 percentage points from the previous assessment.

When asked "What does 2/3 of 9 equal?", results declined appreciably from 1973 to 1978. Eighteen percent of the 9-year-olds could correctly compute the answer in 1973, but in 1978 only 13 percent could give the correct answer. For 13-year-olds the percent giving the correct answer declined from 56 percent to 49 percent; for 17-year-olds the decline was from 81 percent to 73 percent.

The items measuring translation between forms of mathematical expression proved difficult for 9-year-olds. Thirteen-year-olds showed some improvement on these items over the five-year period. Figure 5 presents an item requiring translation from a pictorial to a numerical form. Performance improved substantially between ages 9 and 13. While the percentage of 9-year-olds giving a correct response did not change between assessments, the percentage of 13-year-olds answering correctly increased by 5 percentage points.

FIGURE 5. Percentages of Correct Responses on Items Requiring Translation Assessed in 1973 and 1978

What fractional part of this figure is shaded?



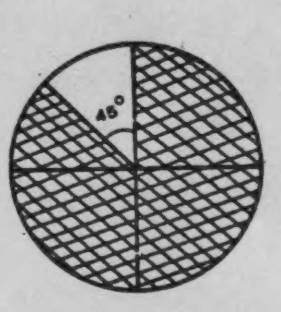
Answer (1/3 or 4/12)

	Percent Correct 1973	Percent Correct 1978	Change
Age 9	19%	20%	1%
Age 13	76%	82%	5%*+

**Change is significant at the .05 level.*

†Figures do not total because of rounding.

Similar results appeared on another item asking for translation of a fraction from a pictorial to a numerical form. Performance of 9-year-olds did not change appreciably on this item, with approximately 11 percent in each assessment answering correctly, while performance of 13-year-olds improved 8 percentage points, with 71 percent answering correctly in 1978. About one-fifth of the 13-year-olds in 1978, a decline of 4 percentage points from 1973, determined the fractional part of the circle that is shaded in the following drawing:



The following problem required 13- and 17-year-olds to translate a verbal expression into a symbolic one. About 17 percent at age 13 and about 46 percent at age 17 completed the translation successfully in each assessment.

Carol earned D dollars during the week. She spent C dollars for clothes and F dollars for food. Write an expression using D, C and F that shows the number of dollars she had left.

Answer D-(C+F) or D-C-F

Fewer 17-year-olds in 1978 were aware that percent represents a number out of 100. Sixty-eight percent in 1978, 5 percent fewer than in 1973, identified a given percent as a number out of 100.

Nine-, 13-, and 17-year-olds were asked to add fractional quantities of liquids pictured in two measuring cups. Students could simply visualize the correct answer from the picture rather than go through the process of adding fractions. About 13 percent of the 9-year-olds gave the correct answer in each assessment year; the percentage of 13-year-olds responding correctly dropped 13 percentage points, from 69 percent in 1973 to 56 percent in 1978; and the percentage of 17-

year-olds giving the right answer remained constant, at approximately 83 percent in each assessment. Percentages of success were considerably lower for an item in which the same fractions pictured in the item discussed above were presented as an addition skill item and were not pictured--2 percent of the 9-year-olds, 35 percent of the 13-year-olds, and 67 percent of the 17-year-olds added correctly on this item. Students typically did better on computational skill exercises than on word problems using the same numbers. In this case, students did much better when they could visualize the solution than when the process of adding fractions was needed.

Seventeen-year-olds responded to a problem that required them to compute one-half of a mixed fraction. Their percentage of success dropped substantially--from 27 percent to 13 percent--between assessments.

Several one-step word problems dealt with percent. About one-fifth of the 13-year-olds and just over half of the 17-year-olds solved the following problem:

A hockey team won five of the 20 games it played.
What percent of the games did it win?

Answer (25%)

Seventeen-year-olds' performance declined 8 percentage points on this item.

When asked to calculate a certain percent of a given number in a word problem, 15 percent at age 13 and 40 percent at age 17 were successful in the second assessment; each age group declined 5 percentage points from its 1973 performance. Percentages of success were similar to those for the previous problem (10 percent at age 13 and 40 percent at age 17) on an item asking teenagers to figure the amount of discount on the price of an item when the percent of discount was given. Performance on this item improved by 3 percentage points for 13-year-olds and did not change appreciably for 17-year-olds between assessments. Instead of multiplying, about 15 percent of the 13-year-olds in 1978, subtracted the percent of discount from the original price, and another 15 percent divided the price by the percent.

Several multistep problems involved the use of percent. Just over one-fourth of the 17-year-olds in each assessment correctly calculated the depreciated value of an object when given the percent of depreciation and the original price. Very few 17-year-olds (about 5 percent in each assessment) successfully determined the original price of an object when the sale price of the object and the percent off were given.

About 10 percent of the 17-year-olds in both 1973 and 1978 solved a problem concerning a taxi fare, in which a base price and additional increments were given for fractions of a mile traveled and the distance traveled was expressed in decimals.

Changes on Measurement Items, Graphs, and Tables

Measurement is another basic and essential use of mathematics. Several items for 9-year-olds dealt with making measurements. One item asked 9-year-olds to mark on a clock face a time that is an hour and 10 minutes later than that shown on another clock. Approximately 45 percent of the 9-year-olds drew the correct time in each assessment.

Nine-year-olds were asked several questions dealing with measurement of time. About one-third of the 9-year-olds in each assessment accurately gave the length of time between two stated times, when they could simply subtract the times and regrouping was not necessary. However, they declined 14 percentage points, from 43 percent to 29 percent, in ability to give a time eight hours later than a stated time. This is a more complicated problem since the time period went past 12:00 a.m.; students could not simply add the hours to the original time.

In another measurement problem, 9- and 13-year-olds used a scale drawing and a ruler to determine the distance between two places. About one-quarter of the 9-year-olds and two-thirds of the 13-year-olds gave the correct distance, a decline of 5 percentage points at each age from 1973. Seventeen-year-olds also answered a question about distance represented on a scale drawing. Forty-two percent in 1978 found the correct distance, a decline of 9 percentage points from 1973.

Approximately 35 percent of the 9-year-olds correctly estimated the length of a given line segment in inches, a decline of 5 percentage points from the first assessment.

Changes in knowledge of measurement may reflect a shift toward greater emphasis on the metric system in the schools' curricula. As seen in Figure 6, knowledge of English unit relationships declined for all three ages, although the overall decline was not as pronounced for the 17-year-olds. On several items dealing with the metric system of measurement, 13- and 17-year-olds showed substantial improvements between 1973 and 1978. Sixty-three percent of the 13-year-olds in 1978, compared with 37 percent in 1973, correctly identified a kilometer as the largest unit in a list of metric units, an improvement of 26 percentage points. Sixty-nine percent of the 17-year-olds completed this task correctly, an improvement of 15 percentage points from 1973. On another metric exercise, in which 17-year-olds were asked to name the English unit most nearly equivalent to a metric unit, performance improved by 12 percentage points, to 71 percent in the second assessment.

FIGURE 6. Percentages of Correct Responses on Measurement Items Assessed in 1973 and 1978

		Percent Correct		
	Age	1973	1978	Change
A. Which is longer?				
2 feet	9	83%	79%	- 4%*
1 yard**	13	94%	93%	- 1%
I don't know.	17	97%	96%	- 1%
B. Which is heavier?				
17 ounces**	9	36%	29%	- 7%*
1 pound	13	72%	63%	-10%*†
I don't know.	17	86%	84%	- 2%
C. Which holds more water?				
3 pints	9	84%	81%	- 3%
2 quarts**	13	92%	91%	- 1%
I don't know.	17	95%	93%	- 2%*

Many of the items assessing measurement skills for teenagers concerned conversions between English units. Seventeen-year-olds showed substantial declines on these items; 13-year-olds' performance also tended to drop, although their declines often are not statistically significant (Figure 7). It is possible that this skill is receiving less emphasis than previously in the schools, and metric units are receiving more attention.

FIGURE 7. Percentages of Correct Responses and Changes in Percentages on Measurement Conversion Items Assessed in 1978

	Age 13		Age 17	
	Percent Correct 1978	Change	Percent Correct 1978	Change
x inches = how many feet?	60%	- 2%	--	--
x pounds = how many ounces?	33%	-10%*	56%	-10%*
x gallons = how many pints?	41%	- 3%	49%	-14%*
x feet = how many yards?	43%	- 3%	59%	- 8%*
Add pounds and ounces	52%	- 4%	70%	- 8%*

**Change is significant at the .05 level.*

**Correct answer

† Figures do not total because of rounding

Graphs. Plotting points and working with graphs of equations proved difficult for most teenagers. Performance did not change appreciably between assessments. Approximately 20 percent of the 13-year-olds successfully plotted the point (3,2) on a graph. At age 17, about 20 percent correctly graphed the equation $y = 2x + 1$. Approximately 15 percent of the 17-year-olds determined the slope of the line $2y = 5x - 8$, and about 12 percent gave the y-intercept of this line. Five percent of them determined the equation of a line when the x- and y-intercepts were given, and 3 percent gave the equation for a circle with the center located at the origin.

Seventeen-year-olds responded to several items demanding interpretation of information presented in graphs. Forty-four percent of them successfully determined the period of greatest profit from a graph displaying separate lines for income and expenses, a decline of 7 percentage points from 1973. Performance did not change on two items that asked students to use a graph exhibiting performance of several cars, in which speed is one axis, time the other, and the cars' speeds at given times are plotted as curves.

Tables. Quantitative information is often presented in graphs or in tabular form, and it is important that students know how to read information presented in this way. Nearly half the 13-year-olds correctly used a table to find proper amounts of sales tax for various amounts--only a slight decline from the previous assessment. Between 75 and 80 percent of the 17-year-olds used the table correctly on these problems, declining about 4 percentage points from 1973.

Thirteen-year-olds improved in their ability to read an air mileage chart--58 percent did so successfully in 1978, an increase of 6 percentage points. Seventeen-year-olds' performance did not change appreciably, with about 65 percent of them using the chart correctly.

Charts and tables can also be used to solve problems. About one-fourth of the 13-year-olds and one-half of the 17-year-olds found the nutritive values of certain foods listed on a chart and then employed that information in calculating nutritive values of a meal. Both teenaged groups declined on this item, with 13-year-olds dropping 8 percentage points and 17-year-olds dropping 6. About 10 percent at age 17 in each assessment correctly used a table--showing automobile injuries, pedestrian injuries, and total number of injuries for different groups--to determine which group had the highest number of pedestrian injuries per total injuries.

Changes in Algebra

Skills in manipulating algebraic symbols include simplifying expressions, solving equations and inequalities, plotting points and graphing equations. Slightly more than one-fifth of the 13-year-olds and just over half of the 17-year-olds in each assessment selected the equivalent expression for $a/b = c/d$ (Figure 8). Both 13- and 17-year-olds declined in their ability to multiply $1/3 \times a/2$. Relatively few 13-year-olds (13 percent in 1973, dropping to 10 percent in 1978) correctly completed this task in either year; however, the percentage correct for 17-year-olds dropped rather sharply, from 54 to 39 percent. Twenty-six percent of the 17-year-olds in 1978 correctly multiplied the binomial factors of a quadratic expression, a decline of 7 percentage points from 1973. Around one-fifth of the 17-year-olds in each assessment successfully gave the binomial factors for a simple quadratic of the form $x^2 + bx + c$.

FIGURE 8. Percentages of Correct Responses on Item About Algebraic Expressions Assessed in 1973 and 1978

If $a/b = c/d$, then which one of the following statements is TRUE?

○ $a/d = b/c$

○ $c/b = a/d$

○ $a \times c = b \times d$

● $a \times d = b \times c$

○ I don't know.

	Percent Correct 1973	Percent Correct 1978	Change
Age 13	24%	21%	- 3%
Age 17	53%	52%	- 1%

Table 5 displays 17-year-olds' proficiency in solving several equations. Seventeen-year-olds' skills in this area appear to decline.

TABLE 5. Percentages of Correct Responses and Changes in Percentages on Items Involving Equations, Age 17

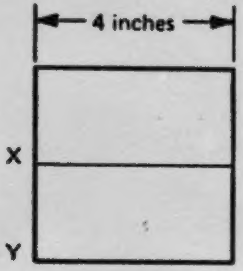
	Age 17 1978	Change
Find missing numerator in equivalent fraction.	72%	-10%*
What value of x satisfies $3x + 6 - 14 = x + 2$?	34%	- 3%
Find solution set of $x^2 - 5x + 6 = 0$.	18%	- 2%
Solve for x and y in a system of linear equations.	12%	- 6%*

**Change is significant at the .05 level.*

Changes in Geometry

Relatively few items measured ability to recognize geometric figures; changes on these items generally were slight. Recognition of names of solids increased considerably from ages 9 to 13 to 17; at all three ages, more students recognized a rectangular solid than a sphere or a cylinder.

Several items assessed understanding of geometric principles. In both assessments, about two-thirds of the 9-year-olds were aware that if one side of a square is a certain length, an adjoining side has to be the same length. Given the following figure



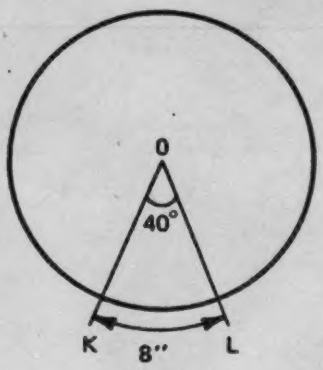
and told that it is a square separated into halves by a line parallel to the base, about a third of the 13-year-olds and just over two-fifths of the 17-year-olds correctly gave the length of line segment XY (2 inches). While performance of 13-year-olds did not change, that of 17-year-olds dropped 9 percentage points. About 30 percent of the

13-year-olds and 19 percent of the 17-year-olds in 1978 gave 4 inches as the length of XY, perhaps an indication that they either did not read the question very carefully or did not realize that the term line segment XY goes not refer to the entire side of the square.

Approximately half the 13-year-olds in both 1973 and 1978 correctly identified the line segment in a circle that is twice as long as the radius. Many 13-year-olds apparently did not realize that such a line must go through the center of a circle. Performance of 17-year-olds declined on this question, from 77 percent in 1973 to 73 percent in 1978.

Seventeen-year-olds had difficulty with several problems requiring the application of geometric concepts. Nearly 20 percent in both 1973 and 1978 solved a problem involving use of the Pythagorean theorem to find the missing side of a triangle. On another problem, the percentage correctly using the proportionality of similar triangles to find the missing side of a triangle dropped from 10 percent to 6 percent.

Seventeen-year-olds were asked to determine the circumference of the following circle with center O:



Twenty percent of them correctly answered 72 inches, a drop of 7 percentage points from 1973. They also were asked to figure the number of cubic feet of concrete needed to fill an area measuring 30 feet x 20 feet x 4 inches. Nine percent were successful in 1978, compared with 13 percent in the previous assessment. Nearly one-fourth of the 17-year-olds in each assessment simply multiplied all the numbers together, neglecting to convert the numbers to the same units.

Changes in Probability and Statistics

Seventeen-year-olds responded to several problems concerning probability and statistics. Success was fairly low on an item involving combinations (5 percent or less) and on another item involving coin-tossing probabilities (an improvement from 2 percent to 5 percent). Figure 9 shows two other items--one concerned with probability and the other with combinations--on which performance dropped about 5 percentage points. A drop of 5 percentage points--18 percent to 13 percent--was also seen in 17-year-olds' ability to calculate a weighted average.

FIGURE 9. Percentages of Correct Responses on Items Involving Probability and Combinations Assessed in 1973 and 1978, Age 17

2, 3, 4, 4, 5, 6, 8, 8, 9, 10

For a party game each number shown above was painted on a different Ping-Pong ball, and the balls were thoroughly mixed up in a bowl. If a ball is picked from the bowl by a blindfolded person, what is the probability that the ball will have a 4 on it?

Answer (1/5)

	Percent Correct		
	1973	1978	Change
Age 17	40%	35%	- 5%*

A combination lock on a trunk has three dials, one showing all 26 letters of the alphabet and the other two showing the 10 digits 0 to 9. Assuming that a combination uses a setting on all three dials, how many different combinations are possible?

Answer (2,600)

	Percent Correct		
	1973	1978	Change
Age 17	20%	15%	- 5%*

**Change is significant at the .05 level.*

B. Trends in Mathematics Achievement from the California Assessment Program: Grade Six*

The Survey of Basic Skills: Grade 6 was developed specifically to assess the students' attainment of mathematics skills taught through the sixth grade level in most California schools. The 160 questions on the Survey were designed to assess students' skills in the areas of arithmetic, geometry, measurement, and probability and statistics. Figure 10 illustrates the emphasis placed on each skill area in the total test. In the figure the skill area of arithmetic is subdivided into number concepts, whole numbers, fractions, and decimals. The emphasis on each area in the test is consistent with the general mathematics curriculum of most California schools and the recommendations in Mathematics Framework for California Public Schools.

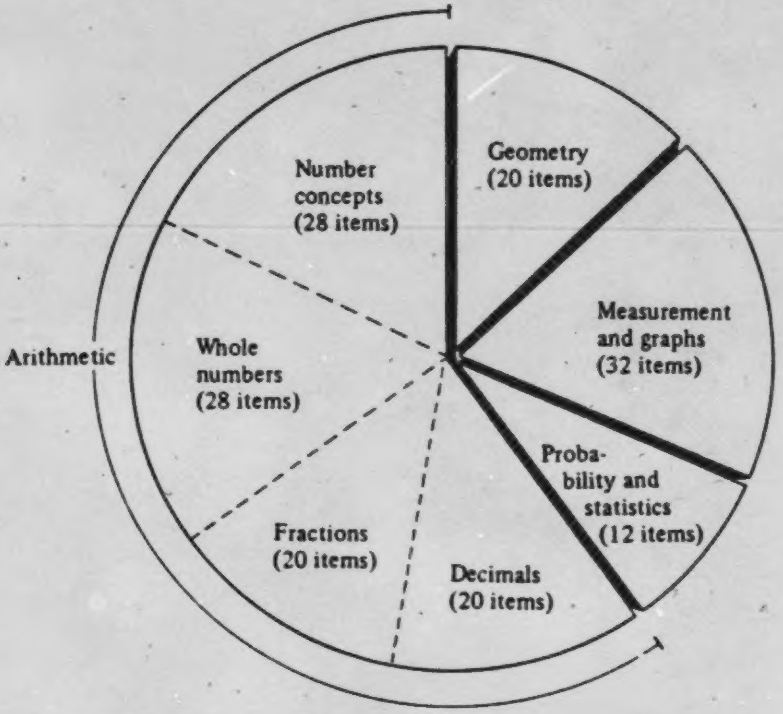


FIGURE 10. Skill area emphases in the *Survey of Basic Skills: Grade 6*

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*Reproduced (with few changes) from Student Achievement in California Schools, 1978-79 Annual Report, pages 86-93.

Mathematics Scores for Grade Six

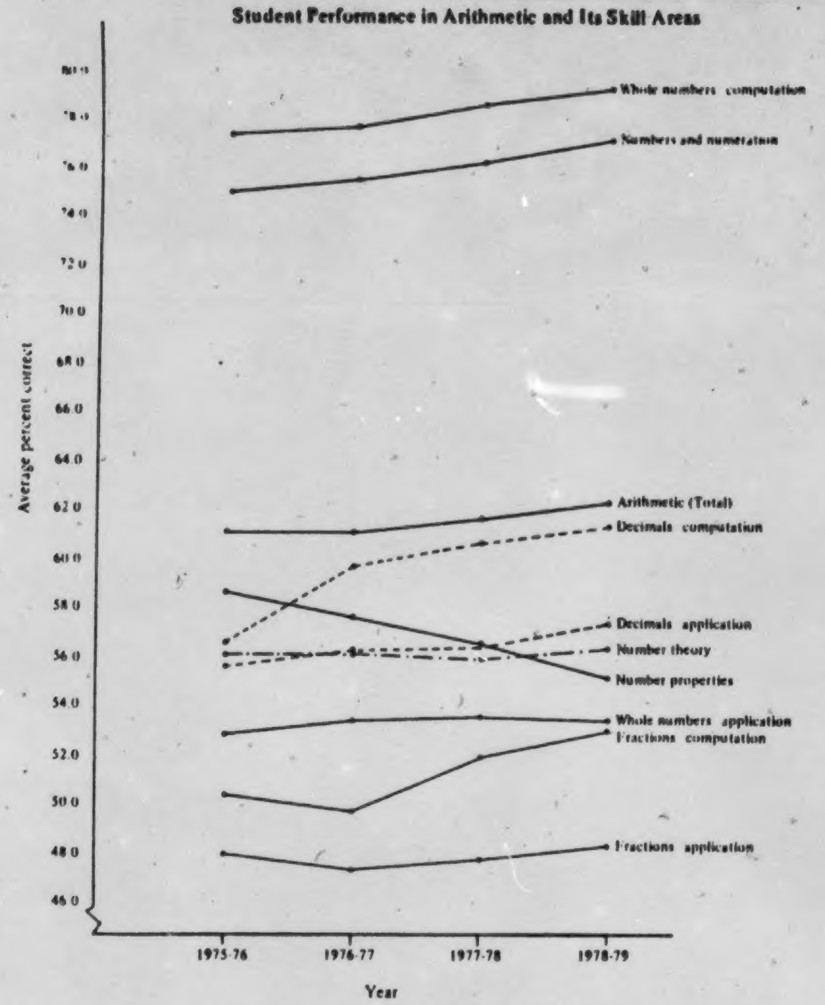
Table 6 contains the sixth grade Survey results for 1975-76 through 1978-79. The last three columns of the table show the changes in scores over the same period.

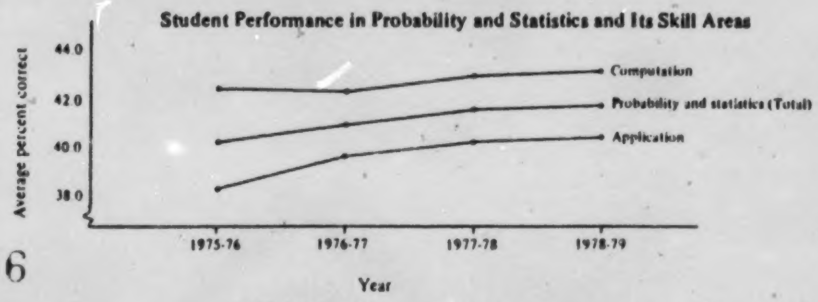
TABLE 6. Mathematics Scores of California Sixth Grade Students on the Survey of Basic Skills: Grade 6

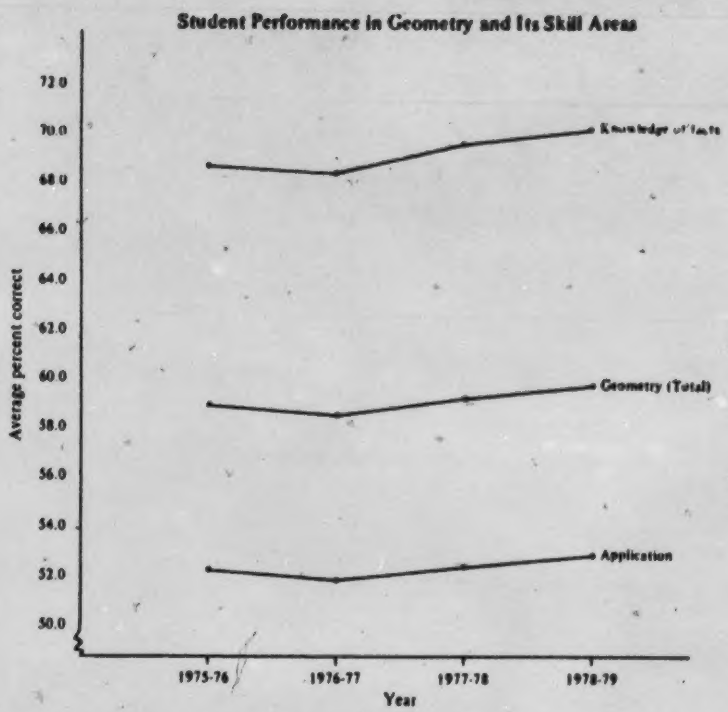
Skill area	Number of questions	Average percent correct				Change		
		1975-76	1976-77	1977-78	1978-79	1975-76 to 1976-77	1976-77 to 1977-78	1977-78 to 1978-79
MATH, TOTAL	160	57.4	57.7	58.5	59.0	+0.3	+0.8	+0.5
Arithmetic	96	61.0	61.0	61.8	62.3	0.0	+0.8	+0.5
Number concepts	28	65.4	65.5	65.6	65.8	+0.1	+0.1	+0.2
Whole numbers	28	66.9	67.5	68.0	68.4	+0.6	+0.5	+0.4
Fractions	20	49.6	49.0	50.6	51.3	-0.6	+1.6	+0.7
Decimals	20	56.3	57.8	59.0	59.9	+1.5	+1.2	+0.9
Geometry	20	58.8	58.5	59.3	59.8	-0.3	+0.8	+0.5
Measurement and graphs	32	52.1	53.5	54.4	55.1	+1.4	+0.9	+0.7
Probability and statistics	12	40.4	40.9	41.6	41.7	+0.5	+0.7	+0.1

A more detailed breakdown of skill area results for the four-year period appears in Figure 11. The following overall conclusions are apparent from the data in Table 6 and Figure 11.

- The overall mathematics scores improved consistently over the four-year period.
- Over the four-year period, students registered the greatest gains in the skill area of decimals in general, and decimal computation in particular. The area of measurement and graphs is the area in which students showed the next greatest gains. The scores for knowledge of facts and applications of measurement also increased.
- Scores in the skill of number properties showed a continuous and significant decline over the four-year period. In all skill areas except the ones mentioned above, students showed small but consistent gains over the period of four years.


Student Performance in Arithmetic and Its Skill Areas


Student Performance in Probability and Statistics and Its Skill Areas


Student Performance in Geometry and Its Skill Areas

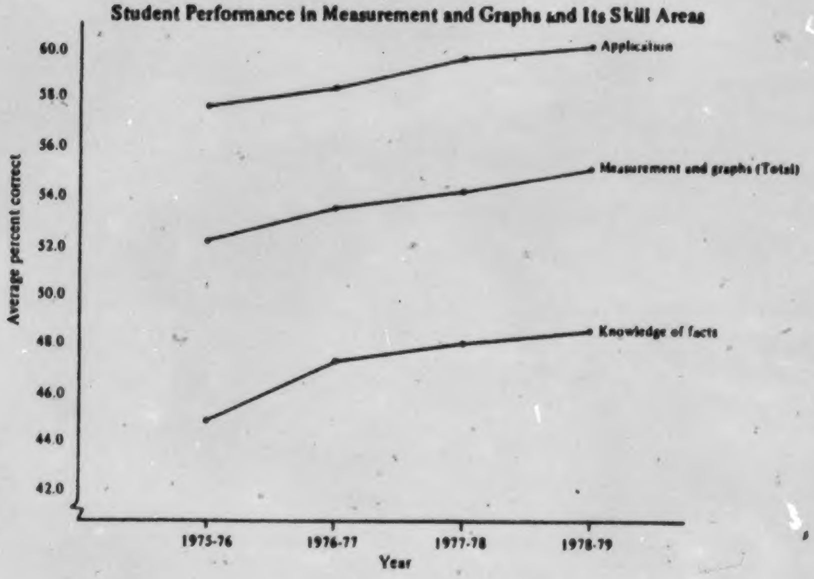

Student Performance in Measurement and Graphs and Its Skill Areas

FIGURE 11. Graphic Representations of Average Mathematics Scores and Changes in Scores on the *Survey of Basic Skills: Grade 6*, 1975-76 through 1978-79

Analysis and Interpretation of Skill Area Results

As in previous years, the Mathematics Assessment Advisory Committee conducted an in-depth review of the mathematics results, by skill area. The committee members judged the adequacy of student performance in light of the difficulty of the questions, the relative emphasis on each skill in a typical classroom, and changes in student performance over a period of four years.

Arithmetic. The arithmetic portion of the Survey consists of a total of 96 questions in four skill areas--number concepts, whole numbers, fractions, and decimals. There was an overall increase of 0.5 percent correct in arithmetic from 1977-78 to 1978-79.

In 1978-79 student performance in arithmetic showed an increase in seven skill areas, and a decrease in two (number properties had a decrease of 1.2 percent correct, and whole number applications had a decrease of 0.1 percent correct). The most dramatic increase over the last four years was in decimal computation, in which sixth grade students registered an increase of 5.0 percent correct. Correspondingly, the most dramatic decrease over the last four years was in number properties.

In the opinion of the advisory committee, the continued decline in the number properties skill is due to a decrease in the emphasis on these concepts in newly adopted textbooks and by classroom teachers. The committee members indicated a need to emphasize number properties to improve students' understanding of mathematics concepts. Example A is illustrative of the distributive property skill that the committee believes needs more emphasis in the classroom.

Example A

Select the correct name for the missing number:

3 X 26 = (3 X □) + (3 X 6)

(19) ○ 2
(12) ○ 6
(34) ● 20
(14) ○ 26
(21) ○ None of these

Percent	Correct
1975-76	40.9
1976-77	37.8
1977-78	36.5
1978-79	33.9

In whole number computation the advisory committee judged that scores were good when the testing began in 1974-75 and that these scores have been increasing significantly each year. The committee also noted that although computation with fractions and decimals has improved, the scores are still low. In particular, division of decimals was identified as a skill needing more attention. Example B is illustrative of this type of item.

Example B

75 ÷ 2.5

(50) ○ .3
(18) ○ 3
(29) ● 30
(3) ○ 300

Percent Correct	
1975-76	26.3
1976-77	28.1
1977-78	28.8
1978-79	28.5

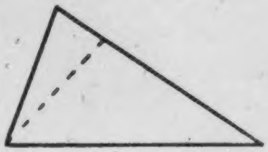
Although student performance has improved on application items over the four-year period (significantly for decimal applications), the advisory committee determined that in general this area still needs more instructional emphasis.

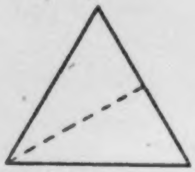
Geometry. The geometry portion of the Survey consists of 20 questions. The average percent correct in the major skill area of geometry increased 0.5 percent correct from 1977-78 to 1978-79. Students increased their average percent correct in six of eight questions concerning knowledge of facts; the average percent correct remained the same on one question and decreased on the other. On the geometric applications students increased their average percent correct in eight of 12 questions and decreased their average percent correct on the other four.

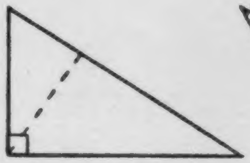
The increase in geometry scores was almost equally divided between knowledge of geometric facts (+0.5) and geometric applications (+0.6) as opposed to the previous year, when most of the increase in geometry was attributed to gains in knowledge of facts (+1.3). Example C is representative of the test items on which scores have increased.

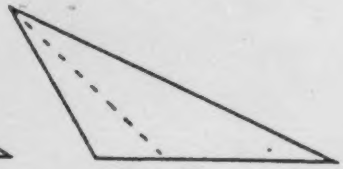
Example C

Which of the following figures is divided by a line of symmetry?


(4) ○


(63) ●


(2) ○


(11) ○

Percent Correct	
1975-76	54.4
1976-77	57.0
1977-78	60.7
1978-79	62.4

The scores in the geometry section seem to indicate that teachers have been placing greater emphasis on informal geometry over the past two years.

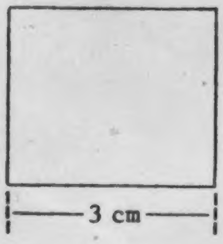
In the judgment of the advisory committee, greater attention needs to be given to formalizing informal geometric concepts, with emphasis on using the appropriate vocabulary to demonstrate an understanding of these geometric concepts. In particular, students need increased instruction in identifying common geometric figures and in describing their parts.

Measurement and graphs. The Survey includes 32 items in the area of measurement and graphs. Fourteen are recall or computation items requiring students to demonstrate an ability to estimate; convert one unit to another; and perform arithmetic operations related to length, mass, volume, and time. The remaining 18 items are word problems dealing with reading and interpretation of graphs (11 items) and measurement of length, area, mass, volume, and time (seven items).

In the overall major skill area of measurement and graphs, students' scores showed an increase of 0.7 percent correct from 1977-78 to 1978-79. Of the 32 items in measurement and graphs, student scores increased on ten of the 14 items involving knowledge of facts and on 17 of the 18 application items.

In the judgment of the advisory committee, the continued improvement in this major skill area reflects the increase in instructional emphasis in California classrooms. The committee noted that students seem to have difficulty distinguishing between the concepts of perimeter and area. For example, when given a problem to compute the area of a square, students most frequently selected the response that was the perimeter. Example D is illustrative of this type of item.

Example D



A side of the square is 3 cm. What is the area of the square?

(18) ○ 3 square cm
(11) ○ 6 square cm
(22) ● 9 square cm
(49) ○ 12 square cm

	Percent Correct
1975-76	19.9
1976-77	20.1
1977-78	22.1
1978-79	21.6

Probability and statistics. The sixth grade Survey includes 12 items on probability and statistics. Six of the items are related to simple statistical computation or based on an intuitive approach to probability. The other six items require the students to apply concepts of probability and statistics to solve problems.

In the major skill area of probability and statistics, the overall percent correct score showed an increase of 0.1 from 1977-78 to 1978-79 (41.6 to 41.7). Seven items showed an increase, and five items showed a decrease.

The advisory committee continues to believe that the scores in the probability and statistics area are far below what should be expected of all students. The lowest scores were found to be on items involving simple terminology, such as "average" and "mean." Since probability and statistical terms are used so frequently in everyday life (for example, "chances of rain," "batting averages," "median salary"), students should be able to understand and use them. Example E is a typical item using common statistical terminology.

Example E

On a mathematics test students obtained the following scores:

68, 75, 80, 86, 95, 100

What is the range of these scores?

(12) ● 32
(5) ○ 42
(19) ○ 68
(26) ○ 100
(38) ○ None of these

Percent Correct	
1975-76	17.2
1976-77	13.7
1977-78	12.9
1978-79	12.1

The advisory committee recommended that more emphasis be placed on classroom instruction in the application of the concepts and skills in probability and statistics since these scores are lower than those on any other section of the mathematics test.

Summary of the Committee's Conclusions and Recommendations

The members of the Mathematics Assessment Advisory Committee were gratified to observe the increase in the mathematics scores of sixth grade students from 1977-78 to 1978-79. The trend of increasing scores in 1978-79 was a continuation of the trends noted during the previous years.

The pattern of strengths and weaknesses discerned by the committee members in their analysis of the sixth-grade mathematics results is summarized in Figure 12.

FIGURE 12. Mathematics Assessment Advisory Committee's Judgments of Strengths and Weaknesses of Sixth-Grade Students in Math on the Basis of Skill Area Results on the Survey of Basic Skills: Grade 6, 1978-79

Areas of strength	Areas in need of improvement
Computing (+, -, x, ÷) whole numbers and simple fractions	Dividing decimals and applying decimals
Adding and subtracting decimals	Using formulas, such as those for perimeter, area, and volume
Recognizing common geometric shapes	Understanding mean, median, and range and computing probability of simple events
Reading a simple bar graph	

C. Trends in Mathematics Achievement from the California Assessment Program: Grade Twelve*

The Survey of Basic Skills: Grade 12 was developed to assess the degree to which students have acquired "basic" mathematics skills by the end of the twelfth grade. A statewide committee compiled objectives and reviewed questions for inclusion in the test. The 198 questions on the Survey were designed to assess students' skills in the areas of arithmetic, algebra, geometry, measurement and graphs, and probability and statistics. Figure 13 illustrates the emphasis given to each skill area in the total test: In the figure the skill area of arithmetic is subdivided into the areas of number concepts, whole numbers, fractions, and decimals.

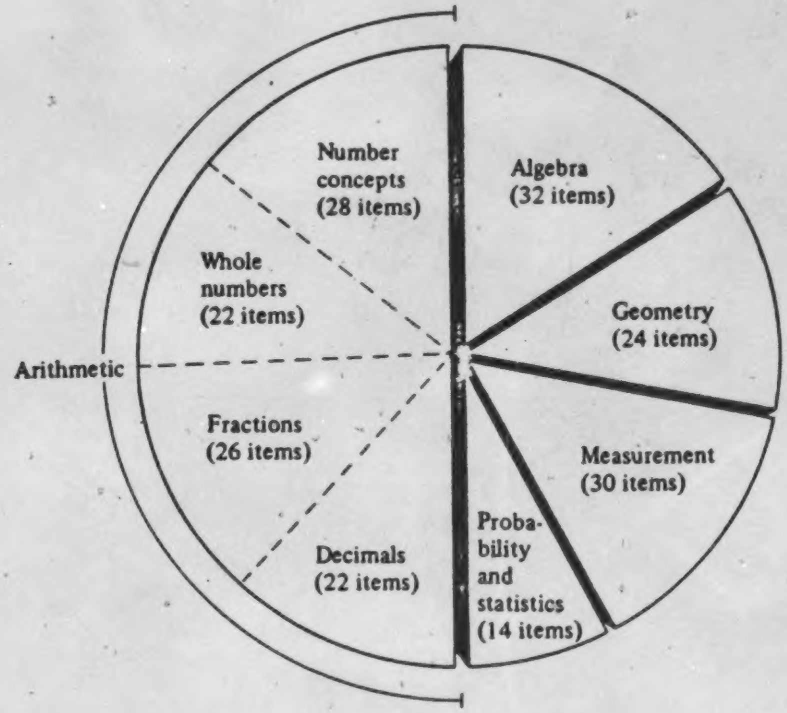


FIGURE 13. Skill Area Emphases in the *Survey of Basic Skills: Grade 12*

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*Reproduced (with few changes) from Student Achievement in California Schools, 1978-79 Annual Report, pp. 93-100.

Mathematics Scores for Grade Twelve

Table 7 contains the twelfth grade Survey results for 1975-76 through 1978-79. The last three columns of the table show the changes in scores over the same period.

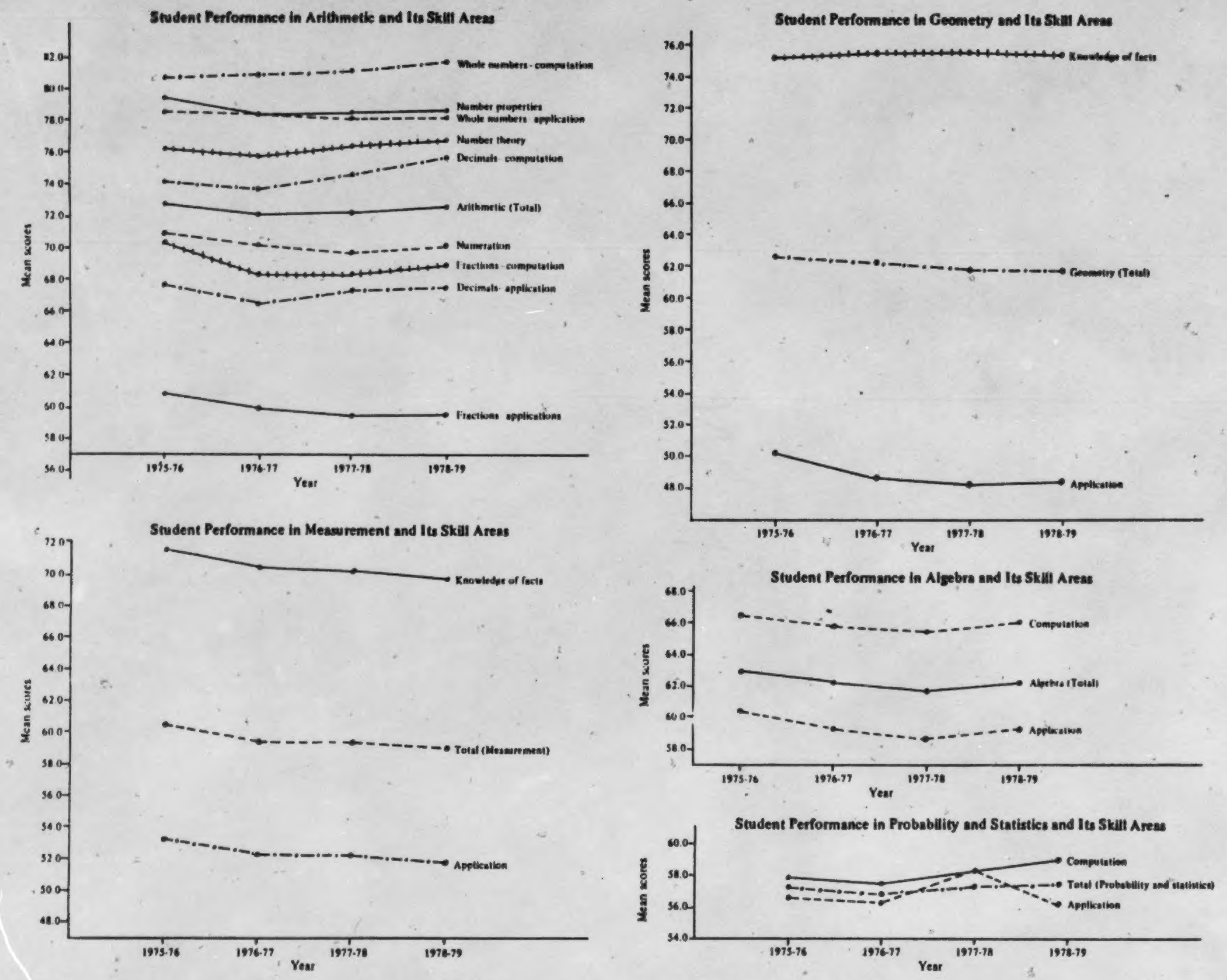
TABLE 7. Mathematics Scores of California Twelfth Grade Students on the Survey of Basic Skills: Grade 12

Skill area	Number of questions	Average percent correct				Change		
		1975-76	1976-77	1977-78	1978-79	1975-76 to 1976-77	1976-77 to 1977-78	1977-78 to 1978-79
MATH, TOTAL	198	67.0	66.3	66.3	66.5	-0.7	0.0	+0.2
Arithmetic	98	72.9	72.1	72.2	72.7	-0.8	+0.1	+0.5
Number concepts	28	74.3	73.5	73.6	73.9	-0.8	+0.1	+0.3
Whole numbers	22	80.1	80.1	80.1	80.6	0.0	0.0	+0.5
Fractions	26	66.0	64.5	64.3	64.7	-1.5	-0.2	+0.4
Decimals	22	71.8	71.2	72.0	72.9	-0.6	+0.8	+0.9
Algebra	32	62.9	62.1	61.8	62.1	-0.8	-0.3	+0.3
Geometry	24	62.7	62.1	61.8	61.8	-0.6	-0.3	0.0
Measurement and graphs	30	60.5	59.5	59.4	59.0	-1.0	-0.1	-0.4
Probability and statistics	14	57.2	56.9	57.3	57.4	-0.3	+0.4	+0.1

A more detailed breakdown of the skill area results for the four-year period is given in Figure 14. The following overall conclusions are apparent from the data in Table 7 and Figure 14.

- The overall mathematics achievement of California twelfth grade students improved slightly in 1978-79, after declining from 1975-76 to 1976-77 and remaining constant from 1976-77 to 1977-78.

- From 1975-76 to 1976-77 achievement declined in all skill areas except the area of whole numbers. The greatest decline was in the area of fractions. From 1976-77 to 1977-78 the decline continued in the skill areas of fractions, algebra, geometry, and measurement. However, the skill areas of decimals and probability and statistics showed gains. In 1978-79, student scores improved in all skill areas except two; the


Student Performance in Arithmetic and Its Skill Areas

Student Performance in Geometry and Its Skill Areas

Student Performance in Measurement and Its Skill Areas

Student Performance in Algebra and Its Skill Areas

Student Performance in Probability and Statistics and Its Skill Areas

FIGURE 14. Graphic Representations of Average Mathematics Scores and Changes in Scores on the *Survey of Basic Skills: Grade 12*, 1975-76 through 1978-79

scores in measurement declined, and the scores in geometry remained the same as in the previous year.

- In 1978-79 the largest gains were registered in decimal computation, followed by whole number computation and number theory.

Analysis and Interpretation of Skill Area Results

As in previous years the California Mathematics Assessment Advisory Committee conducted an in-depth review of the mathematics results, by skill area. The committee members judged the adequacy of student performance in light of the difficulty of the questions, the relative emphasis placed on each skill in a typical classroom, and the changes in student performance over the period of four years.

Arithmetic. The arithmetic portion of the test consists of 98 items in four skill areas--number concepts, whole numbers, fractions, and decimals. There was an overall increase of 0.5 percent correct in arithmetic from 1977-78 to 1978-79.

In the period 1977-78 to 1978-79, student performance in arithmetic increased in all nine subskills. This is the first time, since the initial administration of the current version of the Survey in 1975-76, that scores in arithmetic subskills have uniformly improved.

It was the judgment of the advisory committee that scores in computation with whole numbers and decimals were good when the testing began in 1974-75 and that they have improved modestly over the four-year period. The committee felt that there was still a need for improvement in computation with fractions. Example A is an illustration of the type of item on which scores have increased from 1975-76 through 1978-79.

Example A

$$\begin{array}{r} 2{,}759 \\ \times\ 806 \\ \hline \end{array}$$

(4) ○ 233,274 ○ 2,174,754 (3)
(5) ○ 2,173,754 ● 2,223,754 (88)

Percent Correct	
1975-76	84.1
1976-77	85.7
1977-78	86.4
1978-79	87.6

Although student performance has declined slightly on application items over the four-year period (a decline of 0.7 percent correct), the committee judged that the scores in applications involving whole numbers were still good but that the scores on applications involving fractions and decimals could be improved.

Algebra. In the major skill area of algebra, the scores showed a small but significant increase in 1978-79. On 17 of 32 items the percent correct responses exceeded 65 percent. The committee is encouraged by this report, particularly in view of the fact that about one-fourth of the students taking the Survey had not taken an algebra course.

In general, students do well on items involving simple equations in one unknown, symbolic graphing, simple line graphs, and coordinate graphing. Students do poorly on items involving word problems, equations in two unknowns, and graphs requiring two-step analysis. Example B illustrates how students typically performed on equation-solving questions.

Example B

If $x = 3t$ and $y = 3t$, then $y =$

○ $9x$	○ $3x$	● x	○ $\frac{x}{9}$
(12)	(12)	(70)	(6)

Percent Correct	
1975-76	71.0
1976-77	70.9
1977-78	69.9
1978-79	70.4

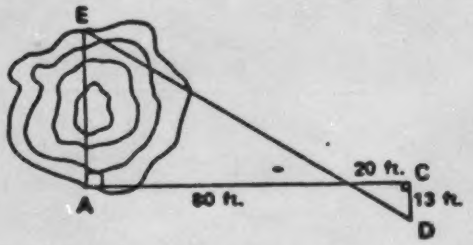
Geometry. The geometry portion of the Survey consists of 24 questions. Half of the questions require students to identify basic geometric sets and figures, and half require them to apply basic geometric knowledge and concepts. The overall average percent correct in 1978-79 was 61.8, which was the same percent correct score as in 1977-78. In the previous two years, the scores had declined by 0.3 and 0.6 percent correct, respectively.

When 1978-79 scores were compared with 1977-78 scores, it was noted that of the 12 questions requiring students to identify geometric figures, the scores increased on three questions, decreased on seven, and remained the same on two. These changes reflected an overall decrease of 0.1 percent correct from the previous year on knowledge of geometric facts.

Of the 12 questions on geometric applications, the scores increased on eight questions and decreased on four questions. These changes amounted to an overall increase of 0.2 percent correct from 1977-78 to 1978-79 on geometric applications. In the previous two years, the scores in this area had decreased by 1.4 and 0.6 percent correct, respectively.

The advisory committee observed that the scores in geometry are no longer declining. However, the committee recommended that increased curricular emphasis be placed on applications of geometric relationships in secondary schools. Example C illustrates a typical skill of this type.

Example C



In the figure above, the lines AE and CD are perpendicular to AC. What is the distance from A to E?

(27) ○ 40 ft.
(33) ● 52 ft.
(17) ○ 60 ft.
(4) ○ 65 ft.
(19) ○ None of these

Percent Correct	
1975-76	36.5
1976-77	33.8
1977-78	32.5
1978-79	32.8

Measurement. The Survey includes 30 items in the area of measurement; 12 are recall or computation items requiring students to estimate, to convert from one unit to another unit, and to perform arithmetic operations related to length, area, and time. The remaining 18 items are word problems dealing with measurement of length, area, volume, time, and distance. A few of these items require the student to convert within the metric system.

In the overall major skill area of measurement, students' scores showed a decline of 0.4 percent correct from 1977-78 to 1978-79. Student scores on seven of the 12 recall or computation items showed a decline, four showed an increase, and the score on one remained the same. Nine of the 18 application items showed a decrease, eight items showed an increase, and the score on one remained the same.

In the judgment of the advisory committee, the continued decline in this major skill area reflects a decrease in instructional emphasis. The committee also noted that the items involving measurement and consumer mathematics showed a continued significant decrease in average percent correct. Example D illustrates an item assessing consumer math skills.

Example D

A housewife will pay the lowest price per ounce for rice if she buys:

(10) ○ 12 ounces for 40 cents
(9) ○ 14 ounces for 45 cents
(36) ● 1 pound, 12 ounces for 85 cents
(45) ○ 2 pounds for 99 cents

Percent Correct	
1975-76	39.6
1976-77	36.8
1977-78	36.2
1978-79	35.8

Probability and statistics. The twelfth grade Survey includes 14 items on probability and statistics. In this major skill area, the average percent correct score for 1978-79 was 57.4, an increase of 0.1 percent correct over the score reported in 1977-78.

Six of the 14 items require students to compute the probability of simple events and such statistics as the mean and median of a set of numbers. For these items the 1978-79 scores showed a small increase over the 1977-78 scores. The scores on the eight application questions in 1978-79 were lower than the 1977-78 scores on the same questions.

The committee judged that most students have learned to compute averages and know the term "mean" as an equivalent term. In fact, the scores on these items show significant improvement. On the other hand, only 17.4 percent of the students could answer correctly an item involving the median of a set of numbers. The committee felt that because basic probability and statistical concepts and terminology are common in day-to-day life, classroom instruction should be designed to emphasize applications of these concepts.

Summary of the Committee's Conclusions and Recommendations

The members of the Mathematics Assessment Advisory Committee were pleased to note a slight upward trend in mathematics scores for the first time in eight years--since the introduction of Iowa Tests of Educational Development in 1969. The scores improved slightly in all skill areas except the skill areas of geometry and measurement. This was the second year in a row in which the scores in decimal computation increased significantly.

The pattern of strengths and weaknesses discerned by the committee members in their analysis of the twelfth grade math results is summarized in Figure 15.

FIGURE 15. Mathematics Assessment Advisory Committee's Judgments of Strengths and Weaknesses of Twelfth-Grade Students in Math on the Basis of Skill Area Results on the Survey of Basic Skills: Grade 12, 1978-79.

Areas of strength	Areas in need of improvement
Computing whole numbers	Computing with mixed fractions, decimals, and percents
Performing applications with whole numbers	Performing applications involving fractions and decimals
Solving equations in one unknown	Solving equations in two unknowns
Reading line and bar graphs	Interpreting data from tables and graphs requiring two-step analysis
Recognizing common geometric terms and shapes	Comprehending geometric relationships
Computing with denominate numbers	Understanding mean, median, and range and computing probability of events

D. Conclusions About Mathematics Achievement

What conclusions can be drawn from the NAEP and California data? In general, the picture of mathematics achievement presented by these two assessments is complementary. Both agree that student performance with whole number computation is quite high, ranging from 80 percent for California twelfth graders to over 90 percent for certain addition problems on the NAEP tests. A simple division problem in the NAEP test was correctly answered by 85 percent of the 17-year-olds. Furthermore, changes in computation with whole numbers seem to have been minimal over the periods tested. California figures show no change on whole number computation between the first, second, and third years of testing, and a slight 0.5 percent gain between the third and fourth years.

Student achievement with fraction and decimal computation was not as good, however. The average percent correct for problems involving decimals for California twelfth graders was 73 percent; for problems involving fractions, this percentage was 69 percent. Furthermore, the NAEP data suggests that performance with fractions may be declining. In 1973, 81 percent of the 17-year-olds tested could find two-thirds of 9; in 1978 only 73 percent could correctly do this multiplication. The California data suggests that while computational ability with fractions has declined overall, the more immediate trend may be more promising. It shows a decrease of 1.5

percent from 1976 to 1977, a decrease of only 0.2 percent from 1977 to 1978, and a modest increase of 0.4 percent from 1978 to 1979. Thus, while improvement in computation with fractions is clearly needed, the trend picture is far from hopeless.

The picture is less encouraging, however, when one considers scores on applications of whole numbers, fractions, and decimals. For California twelfth graders' scores on whole number applications are four percentage points lower than scores on whole number computations. But scores for decimal applications are 8 percent lower than scores for decimal computations, and scores for fraction applications are 10 percent below scores for fraction computations. These application scores have dropped slightly (0.4 percent) for whole numbers and decimals (0.1 percent) and declined more drastically for fractions (1.3 percent).

Furthermore, NAEP data on achievement with percents (which can be considered a specific application of decimals) was disappointing. In 1978, only about half of the 17-year-olds could compute the percent of games won by a hockey team which won five of twenty games played. This was a drop of 8 percent from performance on the same problem in 1973.

Assessment data seems very clear on this point: success in computation does not guarantee success in applying the same computation to a practical situation. Although schools have been successful in teaching whole number computation, they have been only moderately successful in teaching computation with decimals and even less successful in teaching computation with fractions. And students who know "how" to compute frequently do not know "when" or "where" to compute. Schools must broaden their view of basic arithmetic if they expect students to use what they are taught.

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